

# CHEMISTRY

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## After The Atom Year

► THE YEAR just begun will have great difficulty in keeping up the pace. For 1945 was probably the most important year since  $m \times 10^n$  B. C. when that other chemist, Prometheus, practiced his profession of physimistry by stealing fire from the sun. The older type of self-sustaining chain reaction has been, on the whole, a useful discovery. Unlike its modern analogue, it could, from the beginning, be used on a small scale. Today's nuclear scientist has to tame the equivalent of a super forest fire.

Beside setting that task for the future, the past year has brought other marvels. New elements were concocted by man out of fine-spun theories, recently thought too abstruse for practical usefulness. Radar, loran and the proximity fuse have harnessed electromagnetic waves to tasks until lately almost unimagined.

New kinds of chemical and biological attack on rodents, on insects and on disease give mankind a better chance of survival—if only to be exterminated by his own kind.

And finally, the year has brought the beginnings of a plan for a National Science Foundation. It marks recognition by Congress that training in science is essential for carrying on our civilization.

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► *CHEMICAL PLANTS have their unique fire hazards. Fire-fighting equipment peculiar to each combustible material stored should be part of each plant design.*

## Fire Prevention and Fire Hazards

by R. G. FORDYCE

*Monsanto Chemical Co., Research Chemist. Paper presented to Ohio Fire Chief's Association Meeting in Columbus, Ohio.*

► THE CHEMICAL INDUSTRY is probably more fully aware of the danger to life and property from fire hazards than any other large manufacturing group. Not only is this hazard present in many of its processing operations but also many of its products sold to the public are of a highly incendiary nature and their improper use has resulted in serious fire losses.

Before discussing fire hazards and methods that have been developed for flameproofing various materials it might be well to examine basic causes of combustion. Fundamentally, no material can burn unless it is raised

to its ignition point in the presence of oxygen or oxygen containing compounds. Common sense and our own experience tells us that actual ignition occurs readily in the presence of an open flame, spark or other source of intense concentrated heat. Regardless of how the fire is started, however, the temperature of the material is really the controlling factor. A graphic illustration of this fact is the simple demonstration of boiling water in a paper bag over an open flame. In a sense the paper bag has been flameproofed due to the cooling action of the water which prevents

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the paper from reaching its ignition temperature. This cooling principle while universally employed in extinguishing fires has not been successfully applied to flameproofing.

It is well-known that there is a wide variation in the ignition temperatures and flash points of different materials. This variation is apparently due to the heat and chemical stability of the material. Thus, wood for example, starts to decompose and liberate combustible gases below the ignition point and it is these gases which are first ignited when burning occurs. Chemical instability alone will not cause combustion, it is also necessary that the liberated gases be inflammable. Hence, ammonium salts are notoriously unstable but are widely used as flameproofing agents since on decomposition the non-inflammable gas, ammonia, is liberated. Just why certain vapours like gasoline and benzene are highly inflammable and others like chloroform and carbon tetrachloride are not, can not be discussed here, but again the difference relates to the chemical stability and structure of the substance. Thus, in any consideration of flammability it is apparent that the chemical nature of the materials plays a vital role.

Following the above cursory remarks on combustion, the question of how flameproofing agents work, can be logically considered. In spite of the fact that certain flameproofing materials like ammonium chloride (sal ammoniac) and borax have been known for hundreds of years there is still disagreement among workers in the field as to the mechanism by which they protect inflammable materials. At present, three different theories have been advanced. The first

explanation is the obvious one that ammonium salts and the like decompose to give non-inflammable gases thereby excluding oxygen from the material. If this were the entire story, however, certain other salts, notably carbonates and bicarbonates, would be expected to be much more effective than they are. The second explanation postulates that a low melting material like borax melts at elevated temperatures and spreads out over the surface as a thin protective skin thereby preventing free access of oxygen to the combustible material. In the case of borax this is probably true. Finally, it has been suggested that the flameproofing agent alters the course of the chemical reaction during combustion, i.e. during rapid oxidation, so that less inflammable gas is produced and more carbonaceous (charred) material and more water are formed. In the case of acidic materials like diammonium phosphate and ammonium sulfamate a reaction with the cloth or wood is possible and tends to support the last theory.

A great deal of time and money has been spent by various firms to develop flameproofing materials particularly for textiles, paper, wood and other cellulose products. From the myriad patents and literature on the subject the rather startling fact emerges that very few new effective flameproofing agents have been developed. In fact, the materials to be described used alone or in various combinations constitute the basic components in practically all flameproofing formulations. One reservation must be made: Owing to war-time secrecy orders, new effective flameproofing agents may have been de-



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► No flames start up the cloth which was dipped in sulfamic acid, the material only chars.

veloped during the present emergency which have not been reported in the literature.

1. *Diammonium Phosphate* ( $(\text{NH}_4)_2\text{HPO}_4$ ). This salt is usually applied in aqueous solution by dipping canvas and other textiles to be treated. About 15% by weight of the cloth is required to give effective fire prevention and to prevent afterglow. Smaller amounts of diammonium phosphate give protection of decreasing degree. This material has the dis-

advantage of being water soluble hence the fabric must be retreated after it has been wetted.

2. *Diammonium Ethyl Phosphate* ( $(\text{NH}_4)_2\text{C}_2\text{H}_5\text{PO}_4$ ). This salt is applied in the same way as diammonium phosphate and exhibits the same degree of protection. This material does not harshen the treated cloth as much as D.A.P. and gives a better "hand." It is, however, more expensive and is also water soluble.

3. *Boric Acid—Sodium Borate*

( $\text{H}_3\text{BO}_3\text{—Na}_2\text{B}_2\text{O}_4$ ). This material is also applied in aqueous solution and requires slightly more than 25% by weight for fire protection. It does not eliminate afterglow.

4. *Ammonium Sulfamate* ( $\text{NH}_4\text{—SO}_3\text{NH}_2$ ). This is one of the more recently developed flameproofing materials and is likewise applied in aqueous solution, usually until 15–20% by weight is absorbed on the cloth. It imparts excellent flame resistance and fair afterglow characteristics. It is also water-soluble, however, and hence does not give a permanent treatment.

5. *Chlorinated Paraffin and Antimony Oxide*. This formulation possesses the advantage of water insolubility but is more difficult to apply to the fabric. It imparts excellent flame resistance, good waterproofing and fair afterglow properties.

6. *Resin Impregnation*. The use of fabrics impregnated with resins is another recent development of considerable interest. A number of new synthetic materials with good flameproofing properties have been developed within the past few years, and the application of these to inflammable base materials, such as, for example, textiles and paper, is undergoing rapid development at the present time. Treatment with some of these compositions is permanent, the flameproofing action persisting even after numerous washings or dry-cleanings.

7. *Proprietary Compositions*. A large variety of proprietary mixtures have been marketed for fireproofing nearly any base material. Some of these are really quite effective and others are nearly worthless. Since

compositions vary greatly, no generalizations can be made, and it is necessary to test materials of this type carefully, under the intended conditions of use, to determine whether or not satisfactory performance may be expected of them.

The foregoing materials and ammonium chloride ( $\text{NH}_4\text{Cl}$ ) are also used to some extent for impregnating wood to give flame resistance. To force the material in the structural interstices of the wood suitable equipment for alternately applying vacuum and pressure has been developed. In the case of wood, since only the surface layer must be protected, about 10% by weight of flameproofing agent is required. It should be pointed out that, except for special cases, the cost of treating wood in this manner is relatively high at present.

In many formulations, other materials besides the basic components described above are also added. These include; ammonium sulfate ( $(\text{NH}_4)_2\text{SO}_4$ ), ammonium carbonate ( $(\text{NH}_4)_2\text{CO}_3$ ), aluminum hydroxide  $\text{Al}(\text{OH})_3$ , zinc sulfate ( $\text{ZnSO}_4$ ), magnesium sulfate ( $\text{MgSO}_4$ ), sodium phosphate ( $\text{Na}_3\text{PO}_4$ ), zinc chloride ( $\text{ZnCl}_2$ ), urea and others.

Finally it must be stressed that while materials treated with these agents are flame resistant as tested by standard methods, they are not fireproof in the sense of asbestos and all will burn if heated to high enough temperatures. The effect of the flameproofing agent, therefore, is to greatly reduce the rate of combustion of the treated material and to reduce afterglow to a minimum.

In discussing the flameproofing of

textiles a word about the flame resistance of the newer synthetic fibers is in order. At the outset it should be pointed out that the physical form of the fibres greatly influences the potential fire hazard. Thus, a very long pile brushed Angora wool sweater obviously presents a greater hazard than a hard square weave of the same material. The fact that a serious fire accident occurred in the case of the sweater does not mean that Angora fabrics must be condemned per se, but intended applications must be studied carefully from the standpoint of the degree of hazard involved. This principle is of vital importance.

Acetate and Viscose rayons do not exhibit any greater flammability than cotton of the same physical form. Nylon textiles are slow burning materials and offer less fire hazard than cotton. Synthetic fibres sold commercially as Velon, Vinyon, Saran and Geon contain high amounts of chlorine and, therefore, are quite safe from the point of view of flammability since they are self extinguishing, and very useful fabrics are being made of these materials. The use of glass fibres woven into fabrics of various types has provided American industry and homes with useful new textiles which are truly non-inflammable.

Turning our attention from textiles and synthetic fibres to the closely allied field of plastics, it is desirable first of all, to clarify the somewhat confusing array of trade names under which these materials are sold. It has been stressed already that the chemical nature of a material has a vital influence on its flammability. In the chemical industry plastic names are

classified generically according to the chemical structure of the materials and it is essential to associate trade names with chemical structure for a true understanding of potential fire hazards. For convenience, some of this information is tabulated below with flammability data obtained according to A.S.T.M. standard methods. Cellulose nitrate plastics have been purposely excluded and will be treated later.

From these data it is apparent that no special fire hazard is involved in any of the newer plastic materials and that many industrially important plastic materials are self extinguishing. It is interesting to note that the latter materials usually contain chlorine or amino groups in their structure.

Certain plastics are frequently plasticized with materials which reduce the flammability of the composition. Materials commonly used in this connection are tricresyl phosphate, triphenyl phosphate and the Aroclors. Likewise, various inorganic fillers like asbestos, barium sulfate, Fiberglas and the like tend to reduce fire hazard.

The flammable nature of plastic compositions based upon cellulose nitrate has been understood for a great many years, and regulations governing the transportation and storage of such materials are in effect in many localities. Compositions of this type have been used for many types of plastic articles (drawing and calculating instruments, toys, buttons, costume jewelry, covered articles, umbrella handles, combs, brush handles, etc.), for coated fabrics, and for lacquers. A certain amount of hazard is

involved in the manufacture of these, but the hazard to the user is of at least equal importance. The degree of this hazard depends upon the nature of the object involved and upon the likelihood of ignition occurring under conditions which might be encountered in service. The speed with which a plastic object will burn depends upon its thickness, size and other geometry, and upon the way in which

the plastic is combined with other materials. Both speed of burning and likelihood of ignition should be evaluated thoroughly for every intended application, and obviously, if there is reasonable likelihood of ignition taking place and if the burning rate of the finished object is high, cellulose nitrate plastic should not be used where the object will normally be in close contact with the person and not

<i>Chemical Name</i>	<i>Plastic Trade Names</i>	<i>Flammability</i>
Casein	Ameroid	Slow
Cellulose Acetate	Lumarith CA, Plastacele, Fibestos, Nixonite, Tenite I	2.5* to self extinguishing
Cellulose Acetate Butyrate	Tenite II	1.5* to self extinguishing
Ethyl Cellulose	Lumarith E. C., Ethocel	Slow
Polyamide	Nylon	Self extinguishing
Methyl Methacrylate	Lucite, Plexiglas	0.5-1.0*
Allyl Resins	Allite, Allymer	0.3*
Polystyrene	Bakelite PS., Loalin, Styron, Lustron	0.5-1.0*
Vinylidene Chloride	Saran	Self extinguishing
Polyvinyl Chloride	Geon 101, Vinylite Series Q, Koroseal	Self extinguishing
Vinyl Chloride Acetate Resins	Vinylite Series V	Self extinguishing
Polyvinyl Acetals	Vinylite Series X, Butacite, Saflex, Formvar, Alvar	Slow
Polyethylene	Polythene	1.1-1.4*
Melamine Formaldehyde	Melmac, Resimene, Plaskon	Self extinguishing
Urea Formaldehyde	Bakelite, Beetle, Plaskon	Self extinguishing
Phenol Formaldehyde	Bakelite, Catalin, Prystal	Self extinguishing
(Cast Resins, Molding Powders and Laminates)	Durez, Marblette, Duxite, Makalot, Resinox, Indur, Formica	

\* The numbers refer to the rate of burning in inches per minute under the standard conditions of A.S.T.M. tests D568-43, D635-44 and D757-44T. For comparison, values on cellulose nitrate run 10-25 depending on the thickness of the test specimen.

other easily disposed of almost instantly. For example, such objects as spectacle frames, fountain pens and wood heel coverings have been made from cellulose nitrate plastics for years without difficulty, and there seems to be no reason why such applications should be restricted. Conscientious evaluation of the conditions of use is the responsibility of every manufacturer of finished objects, and the manufacturers of basic plastic materials stand willing and ready to assist by providing technical data on the characteristics of these materials.

A discussion of cellulose nitrate leads, naturally, to a consideration of hazards and dangers due to fire, in the surface coating industry where pyroxylin (cellulose nitrate) and other inflammable types of lacquers are often used. These lacquers employ solvents such as butyl acetate, butyl alcohol, amyl acetate, amyl alcohol acetone and thinners such as petroleum spirits, toluene and xylene, all of

which are highly inflammable and more or less volatile materials. Certain noninflammable solvents such as chloromethane and chloroethane have been tried but apparently were not practical for toxicological and other reasons.

Undoubtedly, a serious hazard exists with such lacquers; particularly when sold for home use. Commercial lacquers with flash points of 32°F and lower have been retailed to the public. The hazardous nature of such materials has been recognized for many years, and federal, state and municipal regulations to minimize and control the danger of damage to life and property are generally in effect. If common sense precautions are observed, such as making sure that no open flames or electrical devices are going in the room, and that the room is well ventilated, fires are not likely to occur. However, neither manufacturer nor fire prevention authorities can exert any direct control



over the use of such materials and a certain amount of careless handling by ignorant or negligent persons, with attendant accidents, must be expected. The manufacturer of flammable compositions is obligated to label his products *clearly and forcefully* with respect to the fire hazard involved in their use. More explicit legislation in this respect could do no harm. At best, fire prevention authorities can supervise all industrial and large-scale uses of inflammable coating. Obviously, the danger of major hazard to the community is reduced directly in proportion to the completeness with which such supervision is exercised.

The long-range goal in this industry is the development of coatings which present no flammability hazards in manufacture or application and which are at least self-extinguishing in use in their final form as a solid film. For technical reasons, this goal has not been achieved yet and probably will not be for some time to come. Hence, flammable products must continue to be used for many purposes, and fire prevention activities will continue to be of utmost importance.

Another aspect of nitrocellulose lacquers is the sale of pyroxylin coated toys, games, handles and other small objects that conceivably might come in contact with open flames. These objects may or may not represent a hazard, depending upon the design of the part, the type of application and the conditions of use. In the interests of safety it would seem highly desirable to avoid applications where the solid film will ignite easily, if the object coated is one which is used on or near the person or if it could easily contact sources of ignition un-

der reasonable service conditions. Here again, there are many applications, for example nitrocellulose lacquers on metals, where the finished product presents no hazard even though the coating film is itself inflammable. Hence, this discussion does not mean that nitrocellulose lacquers should be eliminated altogether but rather that their use be governed entirely by the dictates of sound safety practice and of the characteristics of the individual application.

Many other types of surface coatings also present fire hazards in manufacture, application and use. The highly inflammable nature of most oleoresinous varnishes, shellac and oil paints need only be mentioned in this connection.

Certain protective coatings supplied for war uses were alkyd type resins containing antimony oxide and borax for retarding the burning rate and reducing afterglow, and apparently such products were satisfactory. Combination alkyd, urea formaldehyde or melamine formaldehyde baked enamel coatings show improved flame resistance but their use is restricted to applications where baking is possible.

Oleoresinous varnishes and alkyd coatings are frequently used in combination with chlorinated rubber, Aroclors and chlorinated paraffins as flame resistant protective coatings.

Surface coatings of the flame-resistant type described above are not fireproofing agents but rather reduce flammability and, if burning occurs, materially reduce the rate of combustion.

In all of the foregoing discussion only hazards to the user have been

discussed. Another important phase of the problem is concerned with hazard to the firefighter if a blaze should result. Dangers from flame and explosion are obvious, but dangers from the products of combustion are less so. These are very real and serious dangers, however, and an understanding of them is very important in dealing with chemical fires.

Practically any material burning under conditions which restrict the air supply will produce an atmosphere which cannot be entered in safety without special equipment. In many such cases, the oxygen of the air is removed by combustion, leaving only non-respirable gases; only an oxygen mask or air-line helmet is safe for such conditions. In other cases, combustion of the flammable material results in the formation of toxic gases, such as carbon monoxide, hydrocyanic acid, etc., and the dangers from this quarter involving burning wood, paper, textiles, leather, rubber, etc., are well-known to experienced fire officers.

When the flame is fed by an adequate supply of fresh air, combustion of common materials of construction and apparel is reasonably complete and the toxic gases are generally carried away rapidly. When chemicals or some of the synthetic products are involved, however, toxic gases of a highly hazardous nature may be produced. For example, there is the possibility of serious danger if a stock of synthetic rubber known as Buna N should catch fire, particularly under conditions of restricted air supply. This material (known commercially as Hycar OR-25 or Perbunan 35) con-

tains the cyanide grouping. Under certain conditions of extreme heat this material decomposes to liberate the deadly poisonous hydrogen cyanide (prussic acid). In fires of this type, intelligent provision for the protection of personnel can be made only if the nature and characteristics of the particular material involved are thoroughly understood.

Every industrial firefighting officer should know every chemical material in his plant, should understand how it will behave under conditions of slow and rapid combustion, with and without an adequate air supply, and should have made certain that every necessary type of protective equipment has been provided as part of his firefighting equipment. The responsibility on municipal fire-prevention officers is even more weighty. They must not only study every industrial plant, shop, warehouse and store under their jurisdiction for data of this kind, but must ascertain that every battalion chief and other field officer has sufficient knowledge of such hazards to enable adequate measures for protection of the men to be taken almost instantly under emergency conditions.

It would be most helpful if data on such materials and hazards could be appended here, but unfortunately such is beyond the scope of this discussion. The number of possible materials and combinations of materials is so great, and the characteristics are so diverse, that only individualized study of each local condition can be considered adequate. The assistance of a qualified chemist is almost essential for such studies.

## A Sad Song of the Spheres



Once a Doctor found a datum  
On the splitting of the atom  
And gave it to the Government  
to fight the feary foe,  
And the doodle of his dreamer  
Cut a notch in Hiroshima  
And plastered Nagasaki rather low.

Next the Savant, little wotting  
Of the ruin he'd been plotting,  
Asked the Government to tell him  
what it planned on doing then,  
But the Solons, all unblinking,  
Said he'd better stop his thinking—  
"And please don't ever mention it  
again."



The Generals, they told him;  
To silence they would hold him;  
"We're keeping it a secret  
from the other folks," they said.  
(And to banish from his cranium  
All thoughts about uranium  
They tripped him up and sat  
upon his head.)



And they warned the other nations  
That to foster good relations  
They'd keep the atom hanging  
in a Damoclean scheme:  
"The search for fission nuclear  
(We hope we make to you clear)  
Is fishin' in our own restricted  
stream."







And they laid down their conditions  
And they put up their Commissions  
For taping out the problem  
(the hue of tape was red);  
They said: "We're acting rightly  
To tie this thing so tightly."  
And little nations wished they'd  
stood in bed.

Now, the people of Zambeszi  
All began to feel uneasy  
And bought up mystic metals,  
also solvents by the quart,  
While the unrelieved Rhodesians  
And the panicked Polynesians  
Sought swiftly for a chemical retort.



Well, a gifted Eskimo maid  
Had a super-atom (home-made)  
And took it to the Generals  
to see what they would bid;  
The Generals yelled: "Stop it!  
We've got you covered! Drop it!"  
Alas for them! The trouble was,  
she DID.



As splinters of our Sphere  
Were splattered there and here,  
The spectacle left Saturnites  
and Lunars sad and wan;  
The Martians and Venusians  
All thought they had delusions,  
And muttered: "What on Earth  
is going on?"



L'ENVOI

The Moral is:  
What God hath wrought,  
To monkey with  
We hadn't ought;  
But since we have,  
We would be wiser  
Not to be  
An atom-miser.

—POWERS MOULTON.



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**From Roentgen to the  
Era of Atomic Power**

## **Fifty Years of Radiology**

### *Part II*

by ROBERT S. STONE, M.D.

*Dr. Stone, who was in charge of medical research in connection with the atomic energy development, made his presentation of the rise of radiology at a joint session of the American College of Radiology, Chicago Medical Society, Chicago Institute of Medicine and the Physics Club of Chicago. He is professor of radiology at the University of California and has been on leave of absence for the past four years serving as visiting professor at the University of Chicago. Part One of this paper telling of the early history of Roentgenology, was printed in the December number of CHEMISTRY.*

Let us return again to the night of November 8th, 1895. What Roentgen discovered on that night was not a method for medical diagnosis, nor a means of treating disease but the first recognized evidence of a new and unexplored scientific domain. Something passed from the activated Crookes tube to the barium platocyanide crystals through materials that ordinarily stopped light. The stimulus given to physics by this phenomenon has proved to be more important than the medical applications. Let us follow the flow of events that may be said to have started at that time. Roentgen noted that these "rays" ionized air and allowed charges of electricity to flow away from charged bodies. J. J. Thompson investigating this phenomenon discovered elec-

trons and learned much about their behavior. The tremendous field of electronics with radio and television was thereby opened up. Without stopping to mention all the scientific advances involved, one can say that electronics through radar and the proximity bomb played a vital part in winning World War II.

Roentgen noticed that the glass of the tube struck by the beam of cathode rays fluoresced and that it was from this spot that the x-rays seemed to pour forth. Becquerel wondered if it might be the fluorescence that caused the x-rays and started re-investigating some fluorescent uranium salts he had prepared fifteen years before. During these investigations he discovered that uranium emitted rays that behaved much like x-rays. The further work of that scientist and that of Rutherford and Villard revealed that there were three kinds of "rays," one like the x-ray called gamma-rays, one like the cathode rays called beta-rays, and a third less penetrating but more ionizing than the others called alpha-rays. We now know that alpha rays are rapidly moving nuclei of helium, beta rays are fast moving electrons, while gamma rays are very penetrating x-rays. Substances which give off any of these rays were called "radioactive."

The discovery of radioactivity led to even more far reaching events than the study and use of the rays, because

it upset man's idea of the construction of the universe. Prior to this time the atoms of each substance were considered to be indivisible. Now, some atoms were found to be going to pieces and in the process atoms of different but known elements appeared. From one atom of radium came out a small piece which turned out to be the nucleus of a helium atom, and the large part remaining was the nucleus of the atom of the gas, radon. The original radium had spontaneously turned into radon and helium.

In addition to the transformation, the particles coming out of the radium had tremendous energy. Rutherford decided that with such energetic particles it might be possible to break up atoms and so, using the alpha particles from radium to bombard nitrogen, he changed a few atoms of nitrogen into an equal number of atoms of oxygen and hydrogen. It began to appear as if all atoms were made of the same material in different proportions.

By the efforts of different people in different countries it was finally established that atoms were made up of a central nucleus and surrounding electrons. All electrons were the same but the atoms of each element had a characteristic and constant number. Moreover nuclei were made up of protons and neutrons, each element having a definite number of protons in its nucleus but a slightly variable number of neutrons. Protons are the nuclei of hydrogen atoms. Neutrons do not occur free in nature. They must be knocked out of atomic nuclei. After these facts were established and it was shown that all

atomic nuclei except that of hydrogen could be broken up, new methods of breaking or changing them were sought. Apparatus such as the cyclotron, the Van de Graff generator and the betatron was developed by which electrons, neutrons and various atomic nuclei could be hurled with great energies at other atoms. Neutrons were found to be extremely useful missiles because, having no electric charges, they were not deflected by the electric charges of the electrons and atomic nuclei in their path.

It was found that many nuclei when changed from that of one substance to that of another or when internally altered without changing to another substance, became radioactive and, like naturally radioactive elements, gave off one or more of the three radiations—alpha, beta or gamma. These became known as artificially radioactive substances. They could be produced best by the cyclotron before the war and many were available in small quantities and were being used for research and therapy in medicine, but more of that later.

It was expected from physical considerations that neutrons would be valuable for therapy of cancer, possibly being more effective than roentgen rays or gamma rays. At California we were just beginning to evaluate neutron therapy when the war interfered.

The war interfered because of the need of the cyclotron for more urgent work. Neutrons and other atomic missiles were required in the scientific war.

It was found in 1939 that if uranium was bombarded with neutrons,

some of the atoms flew apart into two completely different atoms of about equal weight, but that the combined weight of the two did not equal that of the original uranium atom. This phenomenon is called fission. Whenever it occurs some mass is lost. Years ago, Einstein in working on theories that most of us didn't understand and thought were of little practical value worked out an equation that showed that if mass disappeared the energy which would appear would be equal to the mass multiplied by the square of the velocity of light. Hence it was obvious that the disappearance of even a very small amount of mass would create enormous amounts of energy. In the splitting of uranium such loss of mass was happening and hence undreamed of energy was being set free. The bursting or fission of a uranium atom is over ten-million times more violent than the bursting of a molecule of a modern high explosive.

By many experimental steps it was found that it is only one of the three isotopes of uranium that undergoes fission,  $U^{235}$ , and that not only was energy given out but that more neutrons were given out. Thus once fission of a  $U^{235}$  atom occurred spontaneously or for other causes, if plenty of  $U^{235}$  atoms were present or if properly placed, they would capture some of the neutrons and divide and give out more neutrons and so on. This is called a chain reaction, each link producing energy and materials to cause the next. When such a chain reaction is uncontrolled it causes an explosion such as that over Hiroshima, but if controlled it could be put to useful work.

The problem of first magnitude was to show that a chain reaction could occur and if possible that it could occur with the natural mixture of uranium isotopes. This was done by piling uranium metal, uranium oxide and graphite in a definite way. The first "pile" to start in operation was in the West Stand of Stagg Field at the University of Chicago on December 2nd, 1942, a date as important as that of the Alamogorda explosion. I may say here that the health-physicists were a busy group when the first pile started to operate and we were not sure what radiations the operators or the people on the street would receive—but we did know that the "pile" could be controlled and kept to safe limits.

The uranium<sup>235</sup> is the fissionable material, but the uranium<sup>238</sup> is not passively present. It captures some neutrons and becomes uranium<sup>239</sup>, which decays by emitting beta rays to neptunium<sup>239</sup> and plutonium<sup>239</sup>. Plutonium<sup>239</sup> is extremely valuable because not only is it fissionable like uranium<sup>235</sup> but also, being different chemically from uranium, it can be separated by chemical means so as to get a very pure fissionable material. If piles can operate at high levels lots of plutonium could be made—but in the same process tremendously active radioactive materials would be produced.

Now, where does this connect with our beginning—the discovery of roentgen rays? Let me recall to your mind that Roentgen announced his discovery on December 28, 1895. Less than one month later, a Chicagoan was seeking a cure for his x-ray burns.

By 1900 Codman was able to collect records of 170 cases of x-ray injuries and no doubt many more were never recorded. Dr. Percy Brown collected the cases who had died as a direct result of x-ray exposures and found 28 in the period up to 1935. The suffering of untold hundreds of persons that have not resulted in death is nowhere recorded. The radium industry, especially that branch engaged in painting instrument dials with luminous paint has taken its toll. Hospital and laboratory workers with radium have been affected. The pain and suffering not always ending in death was sometimes worse than death itself. Physicists, physicians, manufacturers, technicians and engineers were all involved in an unnecessary sacrifice for science. Hickey wrote graphically of these pioneers' experiences as follows: "It would seem as if the genii who guarded the special storehouses of radiation resented the invasions of these tireless workers (pioneers in Radiology) and invoked on them the curse of suffering and a tortured deathbed."

There is a Latin Proverb, "Happy is he who gains wisdom from another's mishap." Some of the first scientists to work with x-rays profited by their associates' experiences and protected themselves. Many of the scientists who started the project of making a nuclear chain reacting pile, especially Dr. A. H. Compton, were well aware of what had happened in the past. To go ahead with this project meant the creation of amounts of radioactive materials beyond all previous power of imagination. It meant the creation of tremendous numbers of fast neutrons about which little

was known from the protection angle, and of slow neutrons concerning which no biological data was available. Neutrons and mesotrons were possible hazards suggested in the opinions of some physicists. So a health division was formed in the project with a threefold purpose:

First—to see that the workers were not harmed

Second—to see that the "public" was not harmed

Third—to better understand the method of operation of the various radiations and radioactive materials on living material. Such an understanding should lead to methods of early detection of radiation damage and methods of treating over-exposed personnel.

The health activities rather naturally divided into three parts concerned with (1) Medicine, (2) Physics, (3) Biological Research. The Medical section concerned itself with the direct observation of the workers and tests made on them. The Physics section concerned itself with determining the radiation exposures and methods of controlling them. The Biological section studied the action of various radiations and radioactive materials on animals in order to anticipate and prevent or treat the effects of over-exposure in burns.

Why was all this necessary? In its releases through Wm. L. Lawrence, the Army has allowed the following to be stated regarding the chain reacting piles, "In this structure atoms by the trillions are ripped asunder and hosts of new (isotopes of) elements are constantly being created." "The

energy emitted in the form of radiations is many thousands of times greater than that generated by all the radium isolated in the entire world prior to the outbreak of war." "Such a gigantic quantity of radiation would kill any living thing in its vicinity within a fraction of a second. The atomic Pile therefore created the greatest problem for protecting human life mankind ever faced."

Of course there was no operating pile when the Health Division started and the first job turned out to be a study of the toxicity of uranium and its compounds. Up to 1940 the total amount of uranium metal produced in this country was not more than a few grams. Some uranium salts were used in the ceramics industry, etc. Such practical experience as there was would indicate it was non-toxic but the literature seemed to regard it as one of the most toxic elements, and we were going to need it by the ton. We proved both statements to be true. If injected it is highly toxic, but many of its compounds do not get into the body either through the lungs or the gastro-intestinal tract and are therefore relatively safe to handle. Mice placed in a work-shop filled with uranium oxide dust did better than controls in the laboratory.

When the project wanted a "tolerance" or maximum permissible dose of radiations to which personnel should be exposed we naturally took that accepted by the National Bureau of Standards for x-rays and gamma-rays, namely one-tenth of a roentgen. For fast neutron tolerances we looked to such comparisons with x-rays as could be found, such work as that done on the cyclotron at Berkeley.

Since neutrons were more effective than x-rays, the tolerance established was .01 n (the unit of measurement for neutrons). However, neither the .1 r nor the .01 n rested on a very firm basis. Now that thousands of people were to be involved and millions of dollars of expenditure were to be made, it seemed wise to start new experiments. In general the biologists found that .1r has a factor of safety no greater than 10. The ratio between x-ray roentgens and the fast neutron "n" unit for gross effects on mammals is between 6 and 8, thus justifying the one-hundredth of an n as tolerance.

The so-called "fission products" are a group of radioactive isotopes of 30 or so known elements (8.17) occurring near the middle of the periodic table. The minor dangers from these came from their being handled in the laboratory with attendant inhalation or ingestion problems, or danger to the skin and body from external radiations. The major possible dangers were (1) burning up of a pile, (2) enemy sabotage, blowing up chemical solutions containing large amounts, and (3) enemy uses of these by-products in radioactive warfare. Wigner and Smythe concluded that, "fission products produced in one day's run of a 100,000 kw chain reacting pile might be sufficient to make a large area uninhabitable." (4.27) While we briefly considered the idea of such a use and rapidly discarded it—we had to consider that the Germans might use it.

How those elements produced by fission could get into the body, what tissue they would locate in, how soon they would be excreted and what damage they would do, were all

studied. As an example it was found that radio-strontium can enter through the intestines or the lungs, that it goes mainly to the bones, that it can cause bone tumors and lymphatic tissue tumors and that known amounts can kill 50% of the animals in 30 days.

The obtaining of plutonium, element 94, was the objective of the Metallurgical Project. It was a new element not made before December 1940, and by the end of 1942 there were only about 500 micrograms—not enough to make the head of a pin! (6.34) Since this was all needed for chemical studies none of it could be wasted on animals. After the Clinton pile went into operation and grams of the material became available, micrograms were spared for biological study. It was found that it can enter the body through the lungs and, in very small amounts, through the intestines. It locates mostly in the spleen, liver and bones, and because of either its chemical effects or alpha activity (7.35) it is very poorly tolerated by the body, 1 microgram probably being the maximum permissible dose.

Among the other radioactive substances that caused worry were xenon, and iodine (7.35). Xenon is a gas that combines with no other element. Hence the only way to dispose of it was by dilution in the air. Very little was known about the mixing of gases from a stack in the air. During the war, because of physical and chemical conditions it was not possible to collect enough radioactive xenon to properly study its effects, but by very accurate measurements it was possible to tell that not enough

radiation from it was in the atmosphere near any plant to harm anyone. Radio-iodine had already been studied to some extent before the war. It was known that it could concentrate in the thyroid gland. So far no detectible amounts have entered the thyroid glands of workers.

It would take hours to tell of all the substances studied and the results obtained. The tremendous concrete chemical extraction plants at Hanford Engineer works where the metal from the pile is chemically treated without being seen by the human eye till the radioactivity has been reduced to safe limits; the handling of plutonium in closed hoods, the immense protection shields around the piles all bear evidence to the care taken of the workers. The underground storage in tanks of the fission products, the testing of all waste water for radioactivity and the monitoring of the air all indicate the safety precautions for the community at large.

The possibility of river pollution with radioactive materials brought up the question of the effect of radiation on fish. While this is being studied, it is certain that the amounts entering any river have been so small that they could not damage any living thing.

The effects of radiations on specific organs have been studied by selecting radio-elements that will localize. Effects on the lung are being studied by elements that stick in the lung and do not pass through into the body. Those on the gastrointestinal tract are studied by feeding radio-elements that pass through without absorption and that have such weakly penetrating radiations that



they do not affect adjacent organs. Elements like radio-strontium that localize in the bones are being used to discover what effects are produced there. Several volumes will be required to publish the results of all the work.

All of these studies have been centered around safety in producing the material for atomic bombs. They also throw some light on the biological action of the bomb. There has been considerable confusion in the public press between radiations and radioactive materials. Radiations are atomic particles or photons in motion. Each ray appears and disappears very rapidly. Radioactive materials are those which continue to give out radiations for varying periods of time. When a bomb of either uranium<sup>235</sup> or plutonium<sup>239</sup> explodes a tremendous amount of energy is suddenly released. Some of the energy is in gamma-rays and some in fast neutrons, both of which disperse very rapidly. At the same time a stupendous amount of energy is left in the new fission products in the form of potential radioactivity and this is released subsequent to the explosion, very rapidly at first and then more and more gradually for long periods of time.

The newspaper reports and the reports of returning scientists indicate that many Japanese were damaged by the radiations released at the time of the explosion of the bomb. Some died quickly and others over a period of weeks. The latter had their hair fall out, developed diarrhea, bled from various surfaces, developed ulcerated throats, had their blood cells destroyed and in other ways resembled

animals whose whole bodies were exposed to lethal doses of various kinds of radiations. The radio-active fission products, on the other hand, apparently nearly all went up in the over-heated cloud and were diluted in the upper atmosphere. It is clear that just as people died from and were injured by pressure waves and heat waves, so they died from and were injured by radiation waves at the time of the bomb explosion. Fortunately or otherwise, as you care to view it, the tremendous radioactivity of the fission products themselves was wasted by going off in the cloud. Had the bomb exploded nearer the ground conditions might have been different.

Now let us turn to the constructive side. Surely the atomic age has such a side for medicine. What do we mean by the atomic age? As now used the atomic age is synonymous with atomic bombs and started on July 16th, 1945 at Alamogorda. Atomic bombs have nothing to offer except stimulation in discovering how to treat people over-exposed to radiations. Most people really mean the age of Atomic Power—power obtained from nuclear chain reaction. That age started on December 2nd, 1942. Several controlled chain reacting units have been built since then and it is obvious that they can provide the following:

1. An abundant supply of the particular radioactive isotopes formed in the fission process.
2. A supply of such other radioelements as can be made by bombardment with neutrons of the energies available.
3. A source of slow neutrons.
4. A source of fast neutrons.



All of these were available before chain reacting piles came into existence but in quantities so small as to be very limited in distribution and usefulness.

While trying to anticipate what these tools are going to mean to biology and medicine in the future, it is well to remember that the usefulness of the discharge of electric currents through rarified gases and so-called vacuum tubes was at one time a pure research problem where knowledge was sought for the sake of knowledge. Not one of the early experimenters even thought of the roentgen ray. Even after Roentgen had discovered the x-ray many people thought of it as a tool which would be useful for locating fractures. I do not mean to imply that the use of radioactive materials and neutrons will of necessity create such a change in our medical procedure as have x-rays, but I do feel that there is a definite probability that such will be the case.

The use of artificial radioactive materials for research in medicine and biology is probably the field in which it is easiest to see the usefulness of the new tools. As stated before, many radioactive isotopes were available from cyclotrons before the war, but the limited quantities controlled the type of research done and the number of people that could obtain and work with them. The conservatism of the medical profession in adopting new tools, the same conservatism that was slow in using clinical thermometers, stethoscopes and antiseptic techniques has also played its part here.

Radioactive phosphorus and the

non-radioactive isotopes of nitrogen, carbon, oxygen and hydrogen have already been used with conspicuous success in determining the mechanism of many complex steps in metabolism. They have thrown considerable light on how single atoms are exchanged in living material for other atoms, even in such apparently permanent structures as teeth and bones. The use of radioactive carbon in studies of plant and animal metabolism offers the greatest possibility of advance in the understanding of life processes. Carbon<sup>14</sup> is desired because of its long half-life. The use of very short-lived carbon isotopes has already radically changed the knowledge of photosynthesis. Using piles, Carbon<sup>14</sup> can be made in much greater quantities than before and with this isotope the process of photosynthesis can be further elucidated. No life at all would be possible on Earth if we did not have plant life to synthesize organic matter from the non-organic materials of carbon dioxide and water. Just what significance the understanding of this process will have cannot be foretold. In animal life very little is known about the mechanism of fundamental life processes. Many of these will undoubtedly become clearer when we can trace the tagged radioactive atoms of carbon.

The use of nitrogen and sulphur in the study of protein metabolism offers possibilities of great significance. Phosphorus, strontium and iron have already been used to good advantage and the field of their usefulness can be greatly expanded. There are numerous elements in the body which are required in very small amounts and whose exact usefulness is not

clearly understood. Such of these as boron, manganese, cobalt, etc., can be investigated better with radioactive isotopes. It is reported that the sheep in New Zealand died for lack of cobalt and yet the role that cobalt plays in metabolism is unknown. Copper is known to be an important, if small, ingredient in the human body and yet its function is not clearly understood. Radio-copper can probably be of great value in this study.

The use of radioactive materials in pharmacology offers a very wide field for expansion. It should be possible to follow, as has been done in a few instances, the course of drugs and thereby gain a better insight into why and how they act.

The use of radioelements in the field of therapy is one that still requires a large amount of work. The place of radio-phosphorus in the treatment of leukemia is well established, but with larger quantities available, larger numbers of patients can be treated by different physicians using various techniques of administration. The use of radio-strontium in the treatment of metastatic carcinoma in bone and for other diseases can now be tried in a much larger field than was ever possible before. Radio-iodine which has already proved its usefulness in certain cases of hyperthyroidism can now be used in much greater quantities. These are the obvious things.

One of the hopes for the future is that some chemical may be found which will lodge in cancer cells, at least in much greater concentration than in any other type of cells. If such chemical is not by itself able to kill the cancer then a radio-element may

be attached to it and thus a more effective means of treating cancer may be developed than anything known before. The effectiveness of this would lie in the fact that the distant-metastases as well as the primary lesion would be attacked.

Another field in which radioactive materials from the pile can be used is that of substituting for radium. Elements such as tantalum and cobalt can be placed in the pile and made radioactive in such a way that they give off gamma-rays of high energy. By this means it will be possible to make treatment bombs that will contain hundreds of curies rather than our present small bombs of 2 to 10 curies of radium. Whether such methods will offer any advantage over the million to 20 million or 100 million volt x-ray machines, which are possible now because of developments of transformers, tubes and betatrons, remains to be seen. There is also the possibility that needles could be made of tantalum and kept activated in a pile until desired for use. For interstitial therapy these could replace radium, but since the activity remains in them much longer than in radon they could not replace that gas. However, radiations of various penetrations will be available from different radio-elements so that those therapists who wish to use such varying energies will have them available for any use they care to make of them.

The use of radioactive materials in diagnostic procedures in medicine will expand as these materials become more available. The uptake of radio-iodine by the thyroid gland has been shown to be characteristic in various

types of pathological conditions of that gland. More recently the usefulness of radio-sodium has been established in diagnosing the extent of defective circulation in the extremities in such conditions as immersion foot, arteriosclerosis and thrombo angitis obliterans. Many similar procedures will undoubtedly follow in great profusion when the radioactive elements become available.

Fast neutrons have been used for the treatment of human malignancies since 1938 and some biological experimental work was done before as well as since that time. Two hundred forty-eight patients with presumably incurable cancer were accepted for treatment between September 1939 and February 1943. Twenty six of these were still alive in June 1945. These inconclusive statistics coupled with clinical experience indicates that neutron therapy has been of value but since it has been used under the direction of only one radiologist and no technique given a fair trial, I believe it desirable that fast neutron therapy be further investigated. Data obtained by the physicists indicates that more penetrating neutrons than those already used will be needed to effectively treat deep seated cancer.

The fastest neutrons available from the pile are still in all probability not energetic enough to be of value for anything except the therapy of superficial lesions. We will still be dependent upon cyclotrons for more penetrating neutrons. Just what therapeutic value slow neutrons will have is not yet clear. One method of using them was suggested a few years ago. The element boron captures slow neutrons and immediately emits an

alpha particle which would produce dense ionization for a very short distance. If it could be caused to localize in tumors and the individual then placed in a beam of slow neutrons, possibly even the small number that penetrate to the necessary depth in the body would cause sufficient disruption of the cancer cells to kill them. This possibility deserves further investigation.

It is apparent that the age of using nuclear energy was already here and being used by the Medical profession before a chain reacting pile was started. The science of nuclear change started when Becquerel, stimulated by the work of Roentgen, discovered that it was not the fluorescence of uranium, but the rays coming naturally from it that caused changes in photographic plates. The discovery of radium by the Curies provided the first source of nuclear energy for medical and biological uses. The discovery of the phenomena of artificial radioactivity widened the field and the discovery of the cyclotron was a great stimulus to its advance, because it increased the number and quantity of available radio-elements. Now the atomic power machines, by which is meant those machines utilizing the energy from atomic nuclei to keep them in operation, have again expanded in an unlimited way the possibility for usefulness in research and therapy of radioactive isotopes.

From a continuous stream of scientific development, which in 1895 centered in Roentgen and in 1945 in atomic power, have come numerous side streams that have proved of extreme value to biology and medicine. Those who have taken part in all of

this research have usually been limited to narrow and restricted fields because the minds of most men are so limited in scope that they can encompass only a small portion of any field. The development of each separate portion has required specialization both as to the broad fields of science and as to the narrower sub-divisions. It has been necessary to have physicists like Roentgen and Compton to interpret the physical aspect of radiations, and medical men to adopt these to medicine, and within the medical profession, the radiologists, specialists in radiation who devote their time to the study of the limited field in order that they may use it better for the good of humanity.

On the Atomic Bomb Project we have learned that there must be unlimited cooperation between all those necessary to the advance of the project. The scientists had to discover the fundamental facts, the industrialists had to take these from the laboratory to the factory, the laborers had

to carry out the plans and the whole effort was coordinated by the Army.

To apply the science of radiology in the field of medicine, the radiologist must use the principles developed by the physicists and chemists, and the apparatus developed by the industrialists, the knowledge acquired in medical school, and apply it to the patients selected by the general medical profession. Such science knows no nationalism. Roentgen, a German, discovered x-rays; Becquerel, a Frenchman discovered natural radioactivity; Rutherford, a Canadian, determined the kinds of radiations; Thompson, an Englishman, discovered the electrons; Lawrence an American, discovered the cyclotron. Thus we see that the progress of science jumps from country to country and advances are swift when the free interchange of scientific information is possible throughout the world. The Atomic Age is an international development. As someone has said, "Let us not close the door, lest we lock out more than we keep in."

### *Chemical Analysis By X-Rays*

► **CHEMICAL** analysis of gases, liquids and solids, by shooting a beam of X-rays through them, is a new and rapid means of identifying the chemical elements in the material, developed by Dr. Herman A. Liebhafsky and Dr. E. H. Winslow in the General Electric research laboratory. Another scientist in the laboratory, H. Millard Smith, has found a practical way of measuring the X-ray absorption, on which the new method depends, by a photoelectric X-ray intensity meter.

X-rays are intimately related to the inner atom, so they furnish a means

of counting the numbers and indicating the kinds of atoms by which they are absorbed. The invisible rays fall on fluorescent material which becomes luminous where they strike. This material, called a phosphor, is painted on the glass envelope of a phototube of the multiplier type.

With such a tube the light from the phosphor falls first on a sensitized surface within the tube, and electrons are emitted from it. These electrons are multiplied by electronic amplifiers, producing a current that can be measured.

## Chemical Magic:

# Colorful Flames

by JOSEPH H. KRAUS

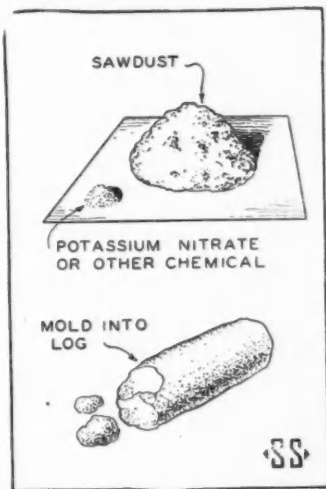
► **CAMP FIRES** will burn brighter next summer and log fires will be more colorful this winter if you throw on the fire lumps of sawdust wet with chemicals and then allowed to dry. The flames will blaze yellow, red, green or blue, depending upon the chemicals used.

First, determine the amount of water which must be added to the sawdust to get the proper consistency. Fill a drinking glass to the brim with water and gradually add this water to a heaping cupful of sawdust, kneading all the time, until it forms a mass of putty-like consistency which will keep its shape when squeezed together.

By measuring the amount of water left in the glass, you can figure how much water was taken up by the sawdust. This tells you how much you need in making your chemical "logs." Discard the batch of sawdust with which you have just been experimenting as this should not be used again unless it is permitted to dry.

If you needed half a glassful of water for your test mixture, add a teaspoonful of potassium nitrate to half a glassful of water and stir until completely dissolved. Use this solution to moisten a cupful of fresh sawdust.

Press the moist sawdust together and either shape it into a cone, roll into a log or mold into a thin paper tube made from a single sheet of writing paper. Set the molded product aside to dry thoroughly—do not



attempt to make it dry faster with artificial heat. Within a few days your sawdust block will be ready for use. When you light it, it will produce a yellowish-white flame.

### Flames of Various Colors

If, instead of using a teaspoonful of potassium nitrate in the water, you substitute half a teaspoonful of strontium nitrate, the flame will be bright red. If a half teaspoonful of barium nitrate is used instead, you will get a brilliant green flame. The addition of a small quantity of copper sulfate to the teaspoonful of potassium nitrate will change the yellowish white flame to blue.

The chemical salts may be obtained in commercial grades from concerns selling laboratory chemical supplies.

Or all the chemicals mentioned can probably be gotten through your local druggist, but he may have to order some of them for you.

A most colorful log for use in a small fireplace or to add a festive spirit to your campfire can be made by mixing batches of sawdust as described above. Take a pinch from one

of the batches and against this press a small quantity from a second batch of moistened sawdust. By adding bits of sawdust moistened with the various water-and-salt combinations, you can form a log which will produce different colored flames.

Short sections from such a log may be used as colored flares. Place them on the ground before lighting.

### *Cashew Oil Sensitivity*

► PERSONS WHO are sensitive to poison ivy become industrial risks when they work with the oily liquid extracted from cashew nut shells, which is now used in the preparation of certain resins and plastics employed in brake linings and insulating materials. A study of the ill effects of this liquid is reported in a recent issue of *Science* by Dr. Harry Keil, of the New York Post-Graduate Medical School and Hospital, and Dr. David Wasserman and Dr. Charles R. Dawson of Columbia University.

The cashew nut tree and poison ivy

are fairly close botanical relatives, though their native habitats are half a world apart. The active principles that make them a menace to sensitive skins are chemically related; both belong to the phenolic group of compounds.

The three investigators also call attention to the fact that men in our armed forces who are sensitive to poison ivy have reacted to the foliage of the cashew nut tree when they came into contact with it in the Southwest Pacific region. Sometimes the effects were disablingly severe, as they occasionally are with poison ivy.

### *Store Big Guns in Sealed Metal Buildings*

► STORAGE of America's big guns, now silent, and other heavy artillery equipment, where rust, corrosion and dust cannot injure them, is a problem that may be solved by the construction of great hermetically-sealed metal containers to house them, in which the destructive air is replaced by an inert gas. This is the solution recommended here by engineers of the U.S. Steel Corporation who devoted months of research and experiment to the problem in co-operation with Army's Ordnance.

The proposal is for a big welded steel container, resembling the Army Quonset hut. Many steel containers of this type have been constructed and are undergoing further analysis and study. After the equipment is placed in them the air, with its corroding factors of oxygen and moisture, will be replaced with nitrogen or other inert gas which should prevent deterioration over a long period of time.

Equipment so preserved will be ready for immediate use in case it is needed. The container will have to be opened with a welding or a burner's torch.

**ANTU, 1080, DDT,  
G-412, G-410, DD.**

## Chemical Warfare Against Pests

➤ *A NUMBER OF important advances have been made in the use of new chemicals in fighting rats, plant diseases, weeds, fungi and a host of other troublesome pests that have long plagued us.*

### **ANTU Rat Poison**

➤ **ANTU** IS A NEW rat poison so powerful that one pound could kill 300,000 rats. It is not dangerous to human beings.

Discovered through taste tests in a psychology laboratory, ANTU was a closely guarded secret during the war.

Credit for the discovery of ANTU as a rat poison goes to Dr. Curt P. Richter, of the Phipps Psychiatric Clinic at Johns Hopkins Hospital in Baltimore. The U. S. Public Health Service's *Public Health Reports* has published a scientific study by Drs. Wm. T. McClosky, M. I. Smith and R. D. Lillie of the National Institute of Health.

The word ANTU is made of the initial letters of the rat poison's chemical name, alpha-naphthyl thiourea. It is a fine gray powder with very little odor or taste. Compared to other rat poisons, ANTU turned out to be twice as poisonous as thallium sulfate and more than 100 times as poisonous as arsenic trioxide and fortified red squill on the basis of the sizes of the killing doses of each.

ANTU has two remarkable features. 1. It acts almost exclusively on rats, leaving humans and most other species unharmed. 2. It kills rats in

an unusual way, causing a dropsy of the lungs so great that the animals are drowned in this fluid from their own bodies. It is the only substance known to produce an edema, or dropsy, that is limited to the lungs.

For rat eradication, ANTU can be used mixed with finely ground corn or wheat; as a spray or dust on fruit or vegetables such as cut-up apples, sweet potatoes, tomatoes, and the like; as a dust, either pure or mixed with flour, on floors and runways; as a dust, on the surface of water where rats are likely to drink; or blown as dust into rat holes and burrows with standard dust pumps used in rat eradication.

Large scale field trials in Baltimore showed that it can produce results very rapidly when properly used. In an emergency, such as an epidemic of rat-borne disease like typhus or plague, probably 95% or more of the rat population of a city could be wiped out in 24 to 48 hours, providing a supply of material and trained personnel were available.

The Baltimore trials also showed that ANTU must be used systematically to be effective. Rats that do not get enough of the poison to be killed outright grow wary about sampling ANTU-poisoned bait another time. The bait must carry enough poison and enough of it must be used to get every rat in the region at one time.

Dr. Richter recommends the city block as the smallest unit for rat eradi-



cation with ANTU, because, while rats move from yard to yard within a block, they rarely cross one of the streets to the next block. Complete coverage, with every rat hole, burrow and runway in every building, cellar and yard within the block containing adequate amounts of ANTU, is essential to success. So also is the co-operation of householders in the area. A preliminary clean-up of the block or area and use of alternate baits were also found important.

ANTU might be used to get rid of mice although it is less effective against these than against rats. Dogs may be poisoned by it and some were accidentally killed during the Baltimore campaign, although none of the more than 500,000 residents who had contact with ANTU were even made sick by it. Rabbits are not affected and chickens can be fed ANTU by the spoonful without harm.

Dogs, fortunately, are pretty well protected against ANTU poisoning by the fact that it causes them to vomit and so get rid of the poison. This and the fact that the chemical is almost insoluble furnish a guide to treatment of humans if any should ever be poisoned by it. No antidote has yet been discovered but immediate washing out of the stomach is advised by Dr. Richter. No fluids should be given. Dr. Richter also advises giving oxygen in case of ANTU poisoning.

ANTU was discovered as a result of studies Dr. Richter had been carrying on before the war, with no idea of developing a rat poison. He was working on the problem of taste as a guide to selection of food, seeking answers to questions such as why some persons develop an abnormal craving for salt or other diet items.

Rats were used in the studies and Dr. Richter found that these animals could select nourishing foods and avoid poisonous substances so long as their taste nerves were intact and functioning.

One afternoon he gave the rats a chemical often used for taste tests in humans. This is phenyl thiourea, which tastes very bitter to most persons though some cannot taste it at all. As is done in the tests on humans, a few crystals of the chemical were put on the tongues of rats.

All the rats in the test were dead the next morning. This was a surprise, because phenyl thiourea previously had been considered non-poisonous. It had been safely used for a long time for taste and inheritance studies in large numbers of people.

The war value of this discovery was immediately apparent. Red squill, which is imported, was no longer available and other rat poisons were either in short supply or dangerous. At the same time, the danger of epidemics of typhus fever and other rat-borne plagues might increase during the war. So, at the suggestion of Col. Perrin Long, Dr. Richter continued to study phenyl thiourea under a grant from the Office of Scientific Research and Development.

He soon found that although the rats in his laboratory would eat enough of the chemical in their food to poison themselves, wild rats in the city dumps and grocery stores of Baltimore were more wary. Apparently the bitter taste of the chemical warned the rats or at least kept them from eating bait poisoned with it.

A search for related chemicals was made with the help of the E. I. du-



Pont de Nemours Company who quickly supplied over 100 chemicals. Of these, alpha-naphthyl thiourea turned out to be the best. It is made from alpha-naphthyl amine and ammonium thiocyanate. These chemicals, commonly used in the dye industry, are not expensive and were not on the list of critical chemicals during the war.

When first supplied, ANTU carried traces of a perfume made in the same building. This doubtless was a pleasing odor to the chemical company's human customers. To the rats, however, it evidently stank and they would have none of it. This difficulty was overcome and ANTU was put into large scale field trials.

Hundreds of thousands of residents of Baltimore, although ignorant of the identity of this new rat poison, soon were gratefully aware of its power to rid their premises of rats.

Surprising and somewhat disappointing was the discovery that while ANTU is very poisonous to the Norway rat, the Alexandrine or black rat commonly found in many parts of the world is not as much affected by the poison.

#### **Use of 1080 Restricted**

Use of 1080, a war-born super-rough-on-rats, is to be restricted to professional rodent-killers for the present at least. The stuff is so poisonous to other animals, and even to human beings, that its general release for civilian use is not considered safe until after considerable further research has been done, giving a basis for precautions and regulations that will make its general distribution less risky.

The new rodenticide has been used with considerable success in cleaning up rat infestations around Army camps and in urban war centers, and also in reducing the numbers of ground squirrels and other wild rodents on rangelands in the West, where they not only destroy forage needed for livestock but also serve as potential reservoirs of bubonic plague through the presence in their fur of disease-carrying fleas.

An example of the extreme poisonousness of 1080 was one bait, in which one pound of it was distributed through two tons of grain. One-thirtieth of an ounce of this poisoned grain was enough to kill a ground squirrel—the single pound of 1080 was, thus potentially able to wipe out more than 1,800,000 of the animals.

Chemically, 1080 is sodium fluoroacetate; the number is simply a convenience-designation.

#### **Victory Over Ragweed**

► VICTORY in hayfever-ridden mankind's hitherto hopeless war against ragweeds seems to be in sight, as a result of experiments with herbicidal sprays conducted by Dr. B. H. Grigsby, of Michigan State College, and botanist to the Michigan Department of Health.

Two chemicals seem to offer most promise in the campaign. One is dinitro-secondary-butyl-phenol, known for greater convenience as G-412. The other is penta-chlor-phenol, whose convenience-designation is G-410. Both are applied in kerosene solutions, with pressure-spray machines.

G-412 gave the most complete kill, Dr. Grigsby reports. The vegetative portions of the plants, as well as the flower spikes, turned brown, and pol-

len release was stopped. G-410 gave a 75% kill in 12 hours, and permanently stopped pollen production, but some of the stems remained alive and continued growth until frost.

Despite the lower killing results reported for G-410, this compound may prove the more desirable for practical use. Dr. Grigsby points out that there is some objection to the immediate and drastic wiping out of ragweed in some spots because, pest though it is, ragweed is given to growing on loose, newly exposed soil and serves as a temporary check on erosion. The two commonest ragweed species are both annuals, so there is no harm in letting them live, if only their power to produce clouds of sneeze-provoking pollen is taken away.

The pollen-stopping chemical sprays cannot be used without caution or limit. The kerosene solvent itself is harmful to many cultivated plants. The chemicals are not toxic to human beings or domestic animals, but they do damage crop plants and so cannot be sprayed indiscriminately over fields and gardens. However, some of the worst ragweed concentrations occur along highways and railroad tracks, in over-grazed pastures, and on neglected vacant lots, rubbish dumps and other waste-land areas in and near cities. Here the weed-killing spray-artillery can be given an unlimited field of fire.

### **Zinc-Containing Fungicide**

➤ A NEW CHEMICAL weapon in defense against the fungi that cause plant diseases has been prepared by chemists of E. I. du Pont de Nemours and Company, and will be ready for use by the opening of another crop

season. It has been given the trade name "Zerlate"—short for zinc-dimethyldithiocarbamate—and is claimed to be more effective than long-used fungicides based on copper and sulfur against certain plant diseases. A close chemical relative, which contains iron instead of zinc, is already in use under the name of "Fermate."

Zerlate combines readily with DDT and other insecticides, so that the same dusting or spraying can be used to combat both fungi and insect pests. It also has repellent action against some insects when used alone; one application is said to protect peaches against Japanese beetles for from seven to ten days.

### **DD Against Wireworms**

➤ DD, A KIND of chemical second cousin to DDT, is the newest weapon that chemistry has added to the arsenal of agriculture for the struggle against insect pests. This compound, which is dichloropropane dichloropropylene when spelled out in full, has been found effective in stopping the ravages of soil-dwelling wireworms, in large-scale field tests conducted by W. H. Lange, University of California entomologist.

The chemical is introduced into the soil with a special drill, about 400 pounds being used to the acre, from one to three weeks before the crop is planted. The fumigating effect of the DD is sufficient to get the wireworms under control, with subsequent great increases in crop yields.

Wireworms are the hard-shelled larvae of click-beetles. There are many species of them, and practically all are destructive pests, feeding on the roots and other underground parts of plants.

## DDT vs. Ship-Fouling Organisms

➤ DDT, though proven able to prevent barnacles from growing on submerged steel plates, is nevertheless of little value as the main active ingredient for anti-fouling paints to be used on ships' bottoms. G. W. Seagren, M. H. Smith and Dr. G. H. Young of the Mellon Institute base their conclusions on an eight-month series of experiments on the Florida coast, where the anti-fouling effectiveness of paints containing DDT and the time-honored anti-fouling copper compounds were compared.

In these experiments, as in earlier ones by other workers, the DDT did prove effective in preventing barnacles from taking hold on the steel test panels. The catch lies in the fact that barnacles are not the only organisms that foul up ships' bottoms. Other animals that help to form the troublesome crusts are included in several zoological orders: mollusks, annelids or jointed worms, hydroids, bryozoa and tunicates. The plant kingdom is represented in the growth complex by several kinds of algae or seaweeds. DDT had no measurable effect on any of these, save only barnacles, whereas a conventional-type copper-containing paint was effective against all of them.

The three researchers therefore conclude: "It thus seems unlikely that this toxicant (DDT) can effectively displace cupriferous and/or mercury pigments in the usual ships' bottom paints."

## Limerock Carrier Dust

➤ FINELY GROUND Florida limerock is found to be an excellent insecticide carrier, or diluent dust, and may be

used for DDT, it is now revealed by the University of Florida where extensive tests have been made by its engineering and industrial experiment station. There is no chemical reaction between it and the DDT, even when they are heated together in the presence of water vapor at 100 degrees Centigrade for several days.

Dusting powders containing insecticides are widely used to control crop pests, particularly where wet sprays are less satisfactory. The dust used must be a gritless type that is inert to the insecticide and harmless to the vegetation. Florida has large deposits of a soft variety of limestone, which when ground is easily freed from grit, and which seems especially suitable for a DDT carrier. Samples of the dust may be obtained from the station.

## Check Orange Fungi

➤ ORANGES MAY be prevented from decaying, with consequent large savings both nutritional and financial, by means of several sulfur-containing organic compounds investigated by Dr. J. F. L. Childs and Dr. E. A. Siegler, of the U. S. Department of Agriculture who conducted investigations at the federal experiment station at Orlando, Florida.

Most of the storage and market spoilage of oranges is traceable to two kinds of fungi that cause stem-end rot and two others that are known respectively as blue and green molds. Damage by all four of these fungi was cut down very materially by three compounds, all characterized by the presence of sulfur in combination with nitrogen-containing atomic structures known as amino groups.

Untreated lots of oranges exposed

to the same conditions of infection underwent decay in percentages ranging from 32.9 to 42.2. Oranges treated with a 5% solution of thioacetamide produced only 1.7% of decayed specimens. Treatment with 8-hydroxyquinoline sulfate and 2-aminothiazole, in the same strength, was not quite so effective, but still reduced decay to a fraction of what it was in untreated oranges.

### Oil Story Now Revealed Developed Under War Clouds

## Great Britain's Petroleum Deposits

➤ OIL PRODUCTION under war clouds, from petroleum deposits in Great Britain, was one of England's war secrets, but now the story is released in London. Since the first producing well struck oil on June 19, 1939, a total of 253 borings have been made in four fields. Of these, 237 were successful wells, producing more than 300,000 tons of crude oil. The average depth of these wells is just over 2,200 feet.

The 1939 well is located near Eaking in Nottinghamshire. The others are in three fields at Kelham Hills, Duke's Woods and Cauntton in the same district. The drilling also proved the existence of coal seams east and southeast of Lincoln, and the presence at Eskdale of layers of potash salts similar to those of the Stassfurt deposits of northwestern Germany.

Oil in small quantities has been known in some parts of Great Britain for a very long while. During the

### Knockout Drops in DDT

➤ OLD-FASHIONED knockout drops, or chloral hydrate, figured in the original formula for making DDT, the "Mickey Finn" of the insect underworld, states F. C. Bishopp of the U. S. Department of Agriculture. The directions for making DDT, as given in the first British patent, call for mixing chloral hydrate or chloral with chlorobenzene, then adding sulfuric acid.

World War I, drilling was undertaken that resulted in a single producing well at Hardstoft, in Derbyshire, which for a long time yielded about one ton a day.

A well was drilled at Portsdown in Hampshire in 1936 to test the Jurassic sediments below the chalk deposits. It was thought that this rock might contain petroleum because rocks of this age on the south coast not far away discharge a little oil into the sea. However, this well, and four others at chosen sites in the south, all failed as producers.

Seepages occurring in the Midlands and northern England led also to unsuccessful drilling. Natural gas, but no oil, was obtained from a well in Yorkshire. An English-American company obtained a little oil from Carboniferous strata in Scotland. The first oil well in England during this campaign was a shallow one at Formby in Lancaster, which yielded three tons a day.

## Chem Quiz

### The Geography of Chemistry

► MANY CHEMICAL ELEMENTS are named for places associated with their discovery. Can you identify the elements asked for in the following questions? Answers on page 43.

1. What 10 elements were named for America, Cypress, Europe, France, Germany, Magnesia, Poland, Scandi-

navia?

2. Give the elements named for three states of the U. S. A. and three provinces of Europe.

3. What four towns have one element each named for them, and what one town has four chemical namesakes.

### Fluorescent Lamps

► BETTER AND BRIGHTER fluorescent lamps will come from a relatively new electronic method of applying to the inner walls of their tubes the essential phosphor coatings that transform the invisible ultraviolet rays emitted inside the tubes into visible light. The new process also simplifies and speeds production, improves the color of the light, and increases the emission efficiency by about 4%.

The new technique was developed by Daniel S. Gustin in the lamp division of Westinghouse Electric Corporation. In reality, it is an electrostatic precipitation onto the inside wall of a tube of the tiny particles of the phosphor from a phosphor "smoke" put in the tube. The method is controllable, produces a uniform coating neither too thin nor too thick. Drying or high-temperature baking is not required, and the coating, when once applied, sticks.

To form the "smoke" Mr. Gustin ground the phosphor finer than tal-

cum powder, inserted the pulverized material in a proper container and passed a jet of air through it. A little of this dusty air is put into the tube to be coated. Then a rounded, pencil-thick rod with a sharpened tip is pulled through the tube. This rod serves as an electrode, introducing into the tube the high voltage necessary to pluck the phosphor particles out of the smoke and precipitate them on the wall of the tube.

When the rod is drawn along the tube interior, the powder particles rushing into its sharpened point become electrically charged with a positive charge. Immediately they are pulled away by electric attraction of the negatively-charged, electrically-conducting heated wall of the tube. The force of the impact causes the particles to adhere to the glass. There they take on an insulating property, leaving only clear glass to attract more powder. This gives the even distribution.

## Chemical Patent Highlights

THE PATENT OFFICE keeps the nation's record of the patentable advances. Dr. Frank Thone in these selections tells about the leading chemical patents. Copies of patents can be obtained by remitting 10 cents in coin, money order, or coupons (not stamps or checks) to the Commissioner of Patents, Washington, D. C., specifying the patent number.

### **Magnesium from Sea Water**

➤ MORE EFFICIENT, hence cheaper, extraction of magnesium from sea water is promised through a newly patented method developed by two chemists employed by the Dow Chemical Company at Midland, Mich., Dr. John J. Grebe and Dr. William C. Bauman. They have assigned to their employing corporation rights in their patent, No. 2,387,898.

Although the application is new, the principle involved has been used for a long time in water-softening systems, in which the undesired minerals are seized and held fast by what is known as a base exchange agent, such as sodium aluminum silicate. Such a base exchange agent is used in the Grebe-Bauman method for extracting the magnesium from the sea water. When the concentration in the base exchange bed has become high enough, the magnesium is dislodged by passing through what is essentially concentrated sea water—a 15% solution of sodium chloride. Partial evaporation of this brings down the common salt in solid crystals; the mag-

nesium chloride flows out, still in solution, and may then be finally evaporated down and the magnesium extracted electrolytically.

### **Smoother Glass**

➤ SMOOTHER SHEET glass is produced by the relatively simple expedient of spinning one of the rollers that flattens the still-soft mass so fast that it carries a film of air on its surface and thereby is kept from direct contact with the hot glass, in the invention on which Dr. Manson L. Devol of Wilkesburg, Pa., obtained patent 2,387,886. Direct contact with the soft, hot glass, Dr. Devol explains, changes the shape of the roller and in time erodes its surface. Protecting the roller with an air film obviates this cause of poor glass surfaces. Rights in the patent have been assigned to the Pittsburgh Plate Glass Company.

### **Evaporated Milk in Glass**

➤ MARKETING evaporated milk in glass bottles instead of the long-familiar tin cans becomes a possibility through the sterilizing machine on which patent 2,388,103 was granted to three Baltimore inventors, Dr. Randall Whitaker, Dr. Robert P. Myers and Robert E. Homberger, assignors to Sealtest, Inc. After the milk has been evaporated and filled into the bottles, the whole operation is conducted either in an atmosphere of an inert gas or under vacuum, in order to exclude flavor-spoiling oxygen. The bottles are spun rapidly in order to agitate the milk, while sterilization heating is

carried on at a temperature between 280 and 300 degrees Fahrenheit for from three to five minutes. Superior color and flavor are claimed for evaporated milk bottled by this process.

#### **Cork-Like Plastic**

► A CORK-LIKE synthetic substance suitable for lining bottle caps is the subject of patent 2,387,730, granted to W. L. Alderson, Jr., of Wilmington, Del., who has assigned his rights to E. I. du Pont de Nemours and Company. The invention is essentially a method for making already known plastics, the polymers of ethylene, uniformly porous. The trick is relatively simple: the polymer is heated in the presence under pressure of ethylene gas, which will of course dissolve in the mass. The pressure is partially removed, whereupon the dissolved gas forms innumerable small bubbles. Then the residual pressure is held constant while the temperature is rapidly reduced, causing the plastic to solidify in its normal elastic state, with the bubbles "frozen" in place.

#### **Rainbow Mirrors**

► A METHOD for depositing substances of different reflecting qualities in near-microscopic, intimately intermixed patterns on sheets of glass, thereby producing mirrors in a large variety of colors and reflecting powers. The inventors, W. H. Colbert of Brackenridge, Pa., and W. L. Morgan of Columbus, Ohio, have assigned rights in their patent, No. 2,387,745, to the Libbey-Owens-Ford Glass Company.

#### **Fire Retardant**

► A FIRE-RETARDING coating for wood and other combustible materials, consisting of some salt of the seaweed-adhesive, an alginate, in which mono-

ammonium phosphate has been mixed. Patent 2,387,865 has been awarded to Arthur Van Kleeck of Madison, Wis., on this invention.

#### **All-Glass Polarizer**

► POLARIZED LIGHT, that is, light in which all wave-fronts are parallel, has been produced for some time by passing ordinary light through filters containing minute crystals that have been brought into parallel alignment. Hitherto these filters have been made of plastic materials, which have to be protected against heat, scratching and other damage by sandwiching them between sheets of glass.

To overcome this production complexity, Harry H. Styll of Southbridge, Mass., has invented an all-glass polarizing lens. Into his glass mix he introduces a quantity of minute mineral crystals of suitable shape, usually crystals of tourmaline or peridote. Then while the glass is still plastic he subjects it to stretching, which brings the axes of the crystals into parallel, and hence polarizing, alignment. After hardening, the glass may be cut and ground into lenses in the ordinary manner. Rights in Mr. Styll's patent, No. 2,387,308, have been assigned to the American Optical Company.

#### **Cheese by Centrifuge**

► A NEW WRINKLE in the preparation of cream cheese is represented in patent 2,387,276, issued to Oscar J. Link of Beaver Dam, Wis., and assigned by him to the Kraft Cheese Company. In the past, the bacteria-curdled cream has been freed of whey by slow filtering in bags. In Mr. Link's method, the whey is whirled out in a centrifugal machine, built on the general lines of a cream separator. By making



the process quicker, chances of contamination of the cheese by alien bacteria and molds are reduced.

### **Pectin Production**

► **MICROORGANISMS**, yeasts this time, figure in a new method for the production of pectin, the stuff that makes jelly jell and is sold in bottles under a variety of trade names. Into the present simple treatment with acidified water, Herbert S. Bailey of Ontario, Calif., introduces a new step, fermentation of the ground-up fruit pomace with yeast, which he states speeds the process and makes it more efficient. Rights in the two patents, Nos. 2,387,635 and 2,387,636, which Mr. Bailey has obtained on his process, are assigned to the California Fruit Growers Exchange.

### **Seaweed Glassine**

► **GLASSINE** paper made more oil-resistant by adding a seaweed product, alginate, to the conventional paper-pulp-and-glycerine mix with which glassine usually starts. This is covered by patent 2,387,429, issued to Paul H. Cate of New York City.

### **X-Ray Insulation**

► **X-RAY GENERATOR** has been made less noisy and more shockproof by insulation in a bath of Freon or a related organic compound. Its two inventors, Z. J. Atlee of Elmhurst, Ill., and J. C. Filmer of Wheaton, Ill., have assigned rights in their patent, No. 2,387,427, to the General Electric X-ray Corporation.

### **Shatterproof Plastic**

► A **SHATTERPROOF** plastic for airplane noses, turrets, etc., made by sandwiching between two hard plastic layers a softer plastic containing a "floating" network of wire. This is by a pair of inventors, Bjorn Andersen of

Maplewood, N. J., and Ernest Schweitzer of East Orange, N. J., who have assigned their rights in patent 2,387,227 to the Celanese Corporation of America.

### **Luminous Tape**

► **LUMINOUS ADHESIVE** tape, for marking doorways and other things necessary to locate in the dark, made by sandwiching a layer of luminescent pigment between two layers of transparent film, bonding them together with rubber cement. The inventor, Frank C. Hilberg of Wilmington, Del., has assigned rights in his patent, No. 2,387,512, to E. I. du Pont de Nemours and Company.

### **Cotton-Picking Machine**

► A **MECHANICAL** cotton picker operating on a new principle is the subject of patent 2,387,004, obtained by Charles R. Berry of Vicksburg, Miss. It is designed to take advantage of the recently developed method of defoliating the cotton plants with a chemical spray before picking the bolls, which greatly simplifies the mechanics of picking.

The machine runs astride of a cotton row, passing the plants through a kind of tunnel with slots in its sides. From one side, a series of flexible arms mounted on a revolving vertical cylinder keep pressing the plants against the other side. Through the slots on that side reach innumerable slender pins mounted on what the inventor calls a carding cylinder, and these pick off the cotton bolls. Next to the carding cylinder, within the machine, is a second cylinder, the doffer, which has rows of bristles that knock the bolls off the carding pins and into a conveyor chute that carries them to an accompanying truck or trailer.



### **Quartz On Mirrors**

► TWO RELATED methods for coating mirrors and other objects with hard-scratch- and acid-resistant quartz are covered by patent 2,386,875, issued to W. L. Morgan of Columbus, Ohio, and by patent 2,386,876, issued to J. C. Ogle, Jr., and A. R. Weinrich, both of Brackenridge, Pa. The big problem has been to get quartz to evaporate, so that coatings could be deposited under vacuum. This is accomplished under these patents by coating the quartz particles either with a metal or a metallic silicate, then heating with an electric coil. Both patents are assigned to the Libby-Owens-Ford Glass Company.

### **Sand-Blasting**

► A SAFER method for sand-blasting, especially of ships' hulls, is covered by patent 2,387,193, taken out by W. H. Swenarton of Montclair, N. J. Corrosion of the metal, which has given trouble when conventional sand-blasting methods have been used on ships, is avoided by carrying the sand particles in a high-pressure jet of water instead of directly in a stream of air.

### **Charcoal from Chips**

► QUICKER and cheaper production of charcoal is the objective sought in patent 2,386,972, the invention of Curt Meyer of Buenos Aires. It is a double drum-shaped furnace, in which wood chips are charred under conditions susceptible to much better control than is possible in the old-fashioned kiln.

### **New Sandpaper**

► AN IMPROVEMENT on conventional sandpaper is contemplated in patent 2,386,780, in which Bert S. Cross of St. Paul, Minn., described a multiple layered arrangement of paper or other

cellulosic material with the sand or other grit bonded to the top layer and the bottom layer consisting of a sized rubber resin. Patent rights are assigned to the Minnesota Mining and Manufacturing Company.

### **Fiberboard Strengthener**

► STRONGER fiberboard for building purposes can be made with shorter application of heat and pressure if the mass of wood, cane or other fiber is first sprayed with a solution of ferric sulfate or other related iron compound, Harry R. Linzell of Long Lake, Ill., states in his preamble to patent 2,388,487, which has just been issued here on the process. Patent rights are assigned to the United States Gypsum Company.

The chemistry of the process is still but dimly understood, Mr. Linzell continues, adding that perhaps the ferric salt has some kind of catalytic effect on the self-bonding substances generated in the heat treatment of lignocellulosic fibers. The effect, however, is to make the final product stronger, more workable and less brittle, as well as more water-resistant.

### **Acid for Pulp**

► TWO SWEDISH inventors, A. J. A. Asplund of Alsten and J. W. Holst of Stockholm, offer a new process for digesting straw and other cheap cellulose materials for the production of paper pulp. Instead of employing the time-honored alkaline sulfate or acid sulfite processes, they use dilute sulfuric or other acid, under steam pressure, and follow the chemical digestion with appropriate mechanical beating, washing, etc. Rights in their patent, No. 2,388,592, are assigned to Aktiebolaget Defibrator, a Swedish corporation.

### Troublesome Iron

➤ IRON EXISTS as a discoloring impurity in some of the crystalline minerals used in making glass, porcelain and other ceramics. A new method of getting rid of it is the subject of patent 2,388,302, issued to W. A. Weyl of State College, Pa., and assigned by him to the American Optical Company. It consists simply in treating the crystals with the familiar, ill-smelling liquid, carbon disulfide. This converts the iron into compounds that can subsequently be dissolved and washed out with dilute hydrochloric and sulfuric acids.

### Continuous Water Gas

➤ THE WIDELY used heating gas known to the trade as "water gas," a mixture of carbon monoxide and hydrogen, is commonly made as a batch process by blowing steam through a mass of incandescent coke, heated by its own partial burning. An English inventor, E. E. Stimson of

Spondon, near Derby, has developed a method for making this gas by a continuous process.

Through the sides of a tower with a central shaft he injects, obliquely, alternate blasts of steam and air, both carrying powdered coke or coal. This sets up a number of adjacent vortices, or artificial whirlwinds. The air-and-coke vortices are ignited, raising the temperature to the point at which the gas-forming reaction with the neighboring steam-and-coke vortices can take place.

Patent 2,388,348, granted on this method, has been assigned to British Celanese, Ltd.

### Riboflavin Stabilizer

➤ A RIBOFLAVIN (one of the B vitamins) solution, is stabilized through the addition of a boron compound in patent 2,388,261, issued to D. V. Frost of Waukegan, Ill., assigned to the Abbott Laboratories.

## Mosquitoes Shine in the Dark

➤ MOSQUITOES aren't being given a break at all any more. First they produce improved repellents, that drive them off a tempting area of exposed human hide with a disappointed "zing!" Then they turn up DDT, which is sure death in submicroscopic doses. Now they spray them with stuff that makes 'em shine in the dark, so their nefarious goings and comings can be traced.

Not that the pests are being crossed with lightning-bugs. Neither is their glow intended for the suffering individual 'skeeter-slapper on porch or lawn. The new trick is primarily for the use of mosquito-fighting scientists,

who want to find out which way and how far the insects fly.

The mosquitoes are marked for later identification by spraying or dusting them with fluorescent compounds—those chemicals that shine with a glimmering light of their own when irradiated with the "invisible light" of ultraviolet rays. Three different compounds have been tested so far, by Dr. John W. Zukel of the U.S. Public Health Service; they make the mosquitoes fluoresce with blue, red and green glows. When mosquitoes thus marked are later recaptured, it is very easy to identify them and to tell where they came from.

**More Lustrous, Tougher,  
Lighter and Odorless**

## New Plastic From Wood and Gas

► **MORE LUSTROUS**, faster to mold, odorless and tough, a new plastic made from natural gas and wood has been introduced to commerce by Celanese Plastics Corporation.

Named Forticel, it is made from cellulose and propionic acid. It was merely a laboratory product until Celanese chemists developed a new process for producing propionic acid for the first time in this country from natural gases in commercial quantities at reasonable prices.

The process is in operation now at the company's new chemical plant at Bishop, Texas. A steady moderate production of Forticel is to be followed by large-scale production later.

Forticel is the culmination of years of intensive research devoted to the study of scores of chemical combinations developed by introducing organic acid or alcohol radicals into the cellulose molecular chain.

Of all the cellulosic compounds produced, Forticel has, in the opinion of Celanese chemists, the best balance of desirable characteristics.

As a thermoplastic the most economical and satisfactory process for making Forticel into finished articles is by injection and extrusion molding. Finished products are characterized by an unusual surface luster and brilliant mold finish, obtained without any mechanical polishing. The molding cycle has been reduced as much as twelve seconds where Forticel replaced cellulose acetate in tests in the same die. In certain instances

this gain in molding time was equivalent to a 25% increase in production. The superior plastic flow quality of Forticel in the molding operation insures virtually invisible weld lines where two streams of plastics meet in the die. These lines are often the seat of mechanical as well as visual flaws. Other scientific tests showed that Forticel has a greater strength in the weld than any of the present commercial cellulose esters.

Forticel is odorless, so that even the most delicately perfumed lipstick or face powder is not affected. Articles made of it can be painted and lacquered without fear of tackiness. The new plastic has a low specific gravity of about 1.2 or less, thus weighing only slightly more than water. Where 100 molded pieces are obtained from a pound of cellulose acetate 108 pieces can be obtained from Forticel. With a toughness of high impact strength not equalled by any other thermoplastic the consumer can expect longer life and better service from articles molded of Forticel even under the roughest treatment. Colorability of the new plastic includes the full range of the color spectrum and it can be produced in colored mottles and intricate color designs. Also Forticel has the same excellent electrical properties as lumarith (cellulose acetate) and exceeds them in that it has the same high dielectric strength but a lower power factor and a lower dielectric constant. Because of low moisture absorption its electrical prop-

erties are little affected by changes in atmospheric conditions.

Special grades of Forticel will be manufactured into sheets and continuous films where good dimensional stability and toughness will tend to further extend the use of the cellulosic plastics.

## *Exposition of Chemical Industries*

► PATTERNS of a productive era, holding promise of tremendous expansion in many new directions will be shown in the 20th Exposition of Chemical Industries, to be held in Grand Central Palace, New York, February 25 to March 2.

The relaxation of wartime restrictions and closing of war industries, plans for reconversion, new product development work, revamping of going plants and properties insure the importance of the chemical exposition as a source of information.

Over 300 exhibitors will provide an all-inclusive coverage of processing equipment, as heretofore, and place increased emphasis on chemical materials in keeping with the stepped up pace of research during the past four years.

At no time since World War I, when this series of expositions was inaugurated, has there been so great a need for clarification of industrial ideas and projects. Every major item entering into the construction and operation of chemical plants and chemical departments of mechanical industries is covered by the list of exhibits. Chemical ingredients, processing chemicals, chemical products, laboratory equipment, research and testing instruments and supplies will be shown.

Numerous uses are predicted for it, including radio housings, steering wheels, house and kitchen utensils, telephones, vacuum cleaner parts, toothbrushes, tool handles, topographic map bases, formed containers, printed dials, electrical insulation, mathematical instruments and glazing materials.

Processing equipment on the list includes a great variety of machines for the preparation of materials by grinding, screening, filtering and others of that class; machines and equipment for mixing, settling, digesting, distilling and otherwise processing; machines for extracting and purifying products of chemical operations, extracting solvents, washing, neutralizing and the like, and finally packaging the finished product, ready for shipment to the consumer.

Associated with processing equipment is a sizable list of exhibits featuring process controls; instruments and apparatus showing many remarkable advances, even since the last Chemical Exposition was held in Madison Square Garden, only two years ago. A noteworthy trend in this class of exhibits is the multiplication of control points covered by a single monitor system.

General plant equipment and supplies, as always, constitute a strong point of the chemical exposition from the practical point of view, as there is a highly selective demand at all times for piping, valves, refractories, tools, conveyors, blowers, pumps, motors, speed reducers, gears, pulleys, shafting and belts and dozens of other appliances that are common currency in mechanical operations of every kind.

**Fragrant Balsam of Medicine  
Became Deadly War Explosive**

## From Balm to Bomb

*Eighth of a Series on Basic and War Chemicals*

by DR. C. M. A. STINE

Vice-President Advisory on Research and Development, E. I. du Pont de Nemours & Co.

► ON THE HIGH plains of northern South America there grows a tree whose fragrant resin many years ago found its way into medicine and which today is widely used to give a pleasant taste to cough syrups.

The resin is known as Balsam of Tolu, after the little town of Tolu, Colombia, and we mention it here only because those strange and liquid syllables, tolu, have been fused into the name of one of the world's most powerful and effective war explosives, tri-nitro-toluene—TNT for short.

It was from a lump of the Balsam of Tolu that a French chemist, Deville, a hundred years ago, isolated a compound which became known as toluol or toluene. Other chemists, at about the same time, obtained the same chemical from pine resin, and, appropriately enough, from "Dragon's Blood," a brilliant red resin from certain Oriental palm trees. And they gave it other names. But toluene is the name that has stuck.

The balsams of the forests have never yielded toluene in quantities, however, and it was coal tar, a toluene source discovered in 1850, that supplied toluene for the dyes; the lacquers; and finally for the explosive TNT that filled the shells of World War I. Coal tar, a by-product of coke production, was also supplying most of the toluene for shells, bombs

and depth charges in the first years of World War II. Then about four years ago the petroleum industry began to build plants for synthesizing this essential chemical from petroleum.

Production of toluene from petroleum and from domestic heating and illuminating gas was started before the end of the first World War, but the Armistice terminated these operations and they were not resumed until after the beginning of World War II, when a new government owned toluene plant was started. Today petroleum is far ahead of coal tar as a source of toluene. This means a total output of scores of millions of gallons. The exact toluene capacity of the country is of course a military secret.

There are two or three processes for synthesizing toluene from the petroleum fractions. The general principle involved is the re-shaping or re-forming of straight-chain or branched hydrocarbon molecules into the six-sided ring-shaped molecule of toluene, which is  $C_6H_5CH_3$ .

One process starts, for example, with the petroleum fraction known as normal heptane, which is a chain of seven carbon atoms, each with a set of hydrogen atoms as appendages. Now when heptane is heated to above 1,000 degrees Fahrenheit and passed

over a suitable catalyst a hydrogen atom is lopped off each end and the disturbed and excited chain molecule whips around and grabs its own tail—like a puppy dog—and in so doing becomes a ring molecule. Further removal of hydrogen atoms pares it down to toluene, which is simply the six-sided benzene ring with a methyl group,  $\text{CH}_3$ , attached at one corner.

In the nitration of toluene to TNT, which is a delicate job requiring great skill and well safeguarded equipment, a nitro group,  $\text{NO}_2$ , it attached at each of three of the six corners of the ring, usually in three steps.

The unique advantage of TNT over other explosives is that it is very powerful yet its sensitiveness may be controlled. For example, a small amount of TNT may be subjected to drop tests, in which a 22-pound

weight is dropped on it from a height of nearly four feet, without exploding. This property is what makes it possible to fill a shell with TNT and to fire the shell from a big gun without the propelling charge of smokeless powder causing the TNT in the shell itself to blow up, and destroy the gun and its crew. The shell may even penetrate a building wall or a tough tank "hide" without going off. When it arrives at its destination, however, the timing mechanism fires the primer, fulminate of mercury, for example. This in turn touches off a booster, which is usually a charge of tetryl, and that detonates the main charge. In other words, TNT can be so controlled that it takes a lot to arouse it, but when this chemical giant is aroused he is a veritable tornado.

## *Wax Emulsion Applied in the Wash*

► EVERYBODY will be able to have water-resistant clothing, as soon as a new war-born wax emulsion, used in large quantities in the armed services, becomes available in civilian markets. Expert treatment of the clothing will be unnecessary; the emulsion is applied simply by adding it to the rinse water in the family wash.

The emulsion can be applied to many types of fabrics as well as to clothing, such as awnings, tenting, window shades and drapes. It makes the material not only water-resistant but less liable to wrinkle and to spot. Pressed garments will keep their shape longer.

This milky-looking wax emulsion, a petroleum product of the Socony-Vacuum Company, is non-toxic and

non-inflammable. It is made up of tiny particles of paraffin wax suspended in a solution of an aluminum salt and water. It is superior to former wax emulsions in which soap is used to emulsify the wax, it is claimed, because such solutions deposit both a soap film and the wax on the cloth.

In laundering, the wax emulsion can be used in conjunction with starch, and it can be used also with moth-proofing and mildew-proofing processes if desired. However used, the wax is invisible on the clothing, does not make the material stiff, and does not fill the spaces between fibers. Clothing that has been treated retains its porous qualities, and summer clothing, therefore, remains ventilated and cool.

## Splitting Protein Molecules In Hair is Chemical Triumph

# Cold Wave Permanents

► THE TRANSFORMATION of straight, lank hair on a woman's head into soft curls and ringlets by the cold wave method of permanent waving turns out to be another triumph of modern chemistry.

Even the cracking of petroleum for the production of ethylene gas is involved, since substances synthesized from this may be used in the process. Details of the chemistry of cold waving are reported in *The Technology Review*, edited at the Massachusetts Institute of Technology.

Briefly, the cold wave method consists of applying chemicals which split certain protein molecules in hair. Among the chemicals that may be used at this stage are sodium sulfide, ammonium thioglycollate, and beta-hydroxyethylmercaptane, synthetic from ethylene gas. The unpleasant odors from these are camouflaged by perfumes.

The atoms of the split molecules are pulled into another pattern by the winding process familiar to those who give and get permanents. Then other chemicals are applied to recombine the atoms. Your hairdresser may refer to this last step as the "neutralizing" process. Chemically, it is an oxidizing process.

Hair is "a bundle of long protein molecules intertwined with one another and linked together crossways at intervals.

"In the cold wave process, the cross-links are broken, the fibrous bundle is bent to the shape which is to be

permanently imparted, and cross-links are established again by new combinations of the parts of the original cross-linkages. As simple as that: The new linkages hold the bundle of molecules in the new shape.

"Proteins are condensed amino acids, long molecules formed by the linking together seriatim of amino acids, the acid end of one molecule being condensed with the amino end of the next, and so on, and so on.

"The amino acids are alike in the respect that they all contain an acid group and an amino group, but they are not all alike in certain other details of the arrangements of their atoms.

"One of them in particular, cystine, which constitutes about 15 per cent of the protein of hair, is made up really of two amino acid molecules linked together crossways by a bridge or link of two sulfur atoms. Every cystine residue in a protein thus establishes one cross-link between two series of condensed amino acid molecules. Another cystine residue may cross-link the two series in another place or it may link each of the series independently to another one.

"The cross-links each grasp only two of the ultimate units of the fiber, but the links are so numerous and so well distributed that they give the bundle a certain pseudoridity of its own, a resiliency, a shape to which it returns of itself when released from any stress which may have distorted it."



The reducing agents such as sodium sulfide which split the cystine molecules are depilatories which soften the hair. If allowed to act long enough, they will finally disintegrate it. This

## *Fluorescence Test Detects Uranium*

► URANIUM, the source of the destructive atomic bomb's tremendous power, can be detected readily in low-grade complex uranium-vanadium ores by a relatively simple and speedy qualitative test developed and used successfully for more than two years by the Bureau of Mines.

Based on the known fact that certain uranium salts fluoresce under ultra-violet light and certain solutions of uranium salts also fluoresce under proper conditions, the Bureau process utilizing short-wave ultraviolet light has furnished a rapid, positive method for uranium determinations and has saved countless laboratory hours in uranium-vanadium ore analyses.

In making the test, the ore is dissolved in a chemical solution in a beaker which is then set on a flat, non-reflecting surface in a dark room. The ultra-violet light is placed on the open top of the beaker. If the ore contains uranium, a bright greenish-yellow light is seen when viewed from a certain angle.

The fluorescence test is described as sensitive enough to indicate amounts of uranium that would ordinarily be detected in the most precise chemical methods, yet is not so sensitive as to give positive reactions with mere traces of uranium. Since its development more than two years ago, the test has been used on hundreds of samples of various kinds and has

is the reason for "test curls" and the careful alarm clock timing of this stage of the cold permanent wave process.

been found satisfactory in all cases. The process also has been found applicable to the detection of uranium in columbium-tantalum ores.

A publication describing the fluorescence test, now available for distribution, marks another important addition to the literature provided by the Bureau's long-established ore-testing program designed to aid in solving problems of special interest to the mining industry.

Report of Investigations 7337, "Fluorescence Test for Uranium," by Claud W. Sill and H. Peterson, may be obtained by writing the Bureau of Mines, Department of the Interior, Washington 25, D. C.

In past years, the Bureau has contributed considerable data on ore-testing and analytical methods for many metals tightly locked in complex ores. Even before the successful smashing of the atom only a few years ago which ultimately led to the development of the deadly atomic bomb, Bureau chemists and physicists assisted in certain phases of scientific research on extraction of radioactive minerals and many of their findings have been included in previous Bureau of Mines publications.

The fluorescence test for uranium was developed by Bureau chemists at the Intermountain Experiment Station at Salt Lake City, Utah, during investigations in the western states on deposits of vanadium with which

uranium often is associated.

Until the development of foreign sources of uranium, low-grade ores of the western states were utilized mainly as a domestic source of uranium, but in the past considerable difficulty was experienced in the determination of uranium in the complex ores.

Because quantitative analyses of uranium-bearing ores involve long laboratory processes, researchers sought a specific test for this metal, sensitive enough to detect small amounts of uranium, and yet simple enough to make the test worth while to apply.

The simplicity and speed of application of the fluorescence method

make it ideal for testing ore samples prior to quantitative analyses and the process wastes none of the sample, permits prompt rejection of samples proved to contain no uranium, and provides a corroborating test to be applied to establish definitely the presence or absence of uranium.

The corroborative test is suggested because certain substances dissolved by acids used in preparing hexavalent uranium salts desensitize and inhibit the fluorescence of uranium solutions. In experimenting both with short-wave and long-wave ultraviolet light, it was found that more satisfactory results were obtained with short-wave ultraviolet light.

## *Glass Armor Protected American Seamen*

► GLASS ARMOR sounds like something out of the Arabian Nights or the tales of King Arthur's Round Table; nevertheless it was extensively used in actual combat by the Navy during the recent war, and was also worn to some extent in combat ashore by the Marines. The story, hitherto held restricted, has now been released by the Navy.

The glass is in the form of exceedingly tough spun-glass fibers woven into fabric and impregnated with a hard plastic. It makes plates that are

claimed to give better protection, weight for weight, than steel. It has the considerable advantage over steel of not throwing off injurious splinters if struck by fragments of exploding projectiles. The plates are placed in pockets in life vests or other garments, and may be jettisoned at will.

Although the new armor material has been used mostly by the Navy, it was originally an Army development. It was invented by Brig. Gen. G. F. Dorion, Q.M.C., and has been given the name Doron in his honor.

## **Answers to Chem Quiz on Page 31**

1. America—Cb; Cypress—Cu; Europe—Eu; France—Ga; Germany—Ge; Magnesia—Mg, Mn; Poland—Po; Scandinavia—Sc, Tm.

2. States of U.S.A.—Ab, Il, Vi;

Provinces of Europe—Ma, Rh, Ru.

3. Copenhagen, Denmark—Hf; Stockholm, Sweden—Ho; Paris, France—Lu; Strontia, Scotland—Sr. Ytterby, Sweden—Er, Tb, Yb, Y.

## War Born Industry Requires New Uses

# Hemp Fiber For Clothing and Textiles

► AMERICA'S war-born hemp industry will require new uses for its products if some 42 processing mills built by the government are to continue in operation. These plants were constructed, and domestic hemp-growing encouraged, to meet a shortage of rope and cordage due to the Japanese control of Manila hemp from the Philippines and elsewhere in the Far East.

"Clothing and textiles from hemp offer one means of nourishing a 'war baby' into a young industry important in national defense," declares *Industrial and Engineering Chemistry*, published by the American Chemical Society. It states also that government retention of these hemp processing plants and expansion of the domestic hemp industry are being urged by some in the interest of national preparedness.

"To utilize these plants at anything near capacity, new industries for hemp, other than cordage, will be needed," the publication says. "Commercial development of hemp for clothing and textiles in this country has attractive possibilities, since hemp

is both the longest and the most highly absorbent natural fiber known."

Among other uses for hemp suggested are use in rug warp, fire hose, canvas, toweling, tropical clothing, by-product paper, and home insulation.

Since the Far Eastern supply of cordage was cut off by the war, American farmers, in Iowa, Illinois, Indiana, Wisconsin and Minnesota particularly, were urged to increase their acreage of hemp. They did so, jumping a pre-war average of 14,000 acres up to 165,000 acres. With the liberation of the Philippines the mills are being closed.

Hemp is a tall plant, related to the mulberry tree. It produces the strongest known vegetable fiber. It was used in both World Wars to supplement stocks of the hard fibers, jute, sisal, and Manila.

Although hemp is the strongest fiber known, its qualities as a soft spinning thread make it more suitable for textile, rug, and specialty uses, the articles states, than for rope and cordage where the cheaper hard materials are predominant.

## On the Back Cover

► STICKS that strike fire roll from automatic machines by the hundreds of millions each day. The photograph shows one of the Diamond Match Company machines. The annual match production of the United States is 196,000,000,000. A striking figure!

**Modern Scientists Attack Atoms;  
Ancient Alchemists Mixed Molecules**

## How Transmutation Works

► **SCIENTISTS**, in one of the steps in making the atomic bomb, have far outdistanced the ancient alchemists. For hundreds of years alchemists tried to make gold out of baser metals. Some of these men were sober researchers, who thought they knew, or were just on the verge of finding out, what it is that makes one metal different from another.

Some alchemists, of course, were crooks and confidence men, fleecing a gullible public. They used the methods the researchers had tried and discarded before their time. Most of these methods consisted in trying to make the metal heavier, as well as give it a yellow color.

People of today's world who seldom have a chance to handle gold in large quantities may not realize that gold is one of the heaviest substances in the world. It is almost as heavy as lead. To the alchemist, who had got a stubborn notion in his mind that all substances are really one, it was only logical to take a lighter metal and add lead. What he really was anxious about was to get the color right.

A typical alchemist's recipe runs: "Fine silver, 1 oz.; brass shavings, 1 oz.; arsenic, 1 oz. Melt first the silver and the brass and then add the arsenic."

Modern scientists know that the trouble with the alchemists' recipes was that they did not affect the atom. They accomplished mixtures of molecules. Scientists had to penetrate much

deeper into the fundamental properties of matter before they could reach the level at which they could change the real nature of the elements.

Chemistry became distinguished from alchemy about the time the United States came into being. During less than two centuries it has concentrated on combinations of molecules. This is one step further into the nature of matter, but not far enough to get beyond the outer shell of the atom.

Atoms are built on the plan of the solar system. Until just before the beginning of the present century chemistry had got from outer space into the system of the atom a distance comparable to the orbit of the sun's planet Pluto. In the past 50 years physicists and chemists have been able to penetrate through the orbits of the circling electrons which are the planets of the atom and reach the nuclear sun itself.

Transmutation of one element into another, which is now an accomplished fact, is done by striking the atomic sun with a projectile from outside the system, making a direct hit which smashes the sun to pieces. It is easy to imagine that the forces set in motion by the flying fragments are as tremendous, on the small scale of the atom, as would be the cosmic forces let loose if such an accident should happen to the central sun of our own solar system.

# Соотношеніе свойствъ съ атомнымъ вѣсомъ элементовъ.

Д. Менделѣева.

но въ ней, мнѣ кажется, уже ясно выражается примѣнимость представляемаго мною начала ко всей совокупности элементовъ, паче которыхъ извѣстенъ съ достовѣрностію. На этотъ разъ я и желаю преимущественно найти общую систему элементовъ. Вотъ этотъ опытъ:

			Ti=50	Zr=90	?=150.
			V=51	Nb=94	Ta=182
			Cr=52	Mo=96	W=186.
			Mn=55	Rh=104,4	Pt=197,4
			Fe=56	Ru=104,4	Ir=198.
		Ni=Co=59	Pt=106,4	Os=199.	
II=1		Cu=63,4	Ag=108	Hg=200.	
	Be=9,4	Mg=24	Zn=65,2	Cd=112	
	B=11	Al=27,4	?=68	Ur=116	Au=197?
	C=12	Si=28	?=70	Sn=118	
	N=14	P=31	As=75	Sb=122	Bi=210
	O=16	S=32	Se=79,4	Te=128?	
	F=19	Cl=35,5	Br=80	I=127	
Li=7	Na=23	K=39	Rb=85,4	Cs=133	Tl=204
		Ca=40	Sr=87,6	Ba=137	Pb=207
		?=45	Ce=92		
		?Er=56	La=94		
		?Yt=60	Di=95		
		?In=75,6	Th=118?		

» MENDELEEFF's original table. Note that the atomic weight of Uranium was at that time believed to be 116, half the true value.

**The Famous Descriptions of Elements  
Verified in Their Author's Lifetime**

# Predicting Undiscovered Elements

## A Classic of Chemistry

► MENDELEEFF (or Mendelyev) in a lecture given in England in 1889 told of his gratification over the way the elements he predicted in this paper fulfilled his descriptions from theoretical considerations, upon their dis-

covery a few years later. The great Russian chemist actually foretold, at one time or another, the properties of all the elements he believed missing from his table.

## The Periodic Law

THE NATURAL SYSTEM OF ELEMENTS AND ITS USE FOR THE PREDICTION OF PROPERTIES OF THE UNDISCOVERED ELEMENTS *By D. Mendelyev, in Journal of the Russian Chemical Society, Vol. 3, St. Petersburg, 1871. Translated from the Russian by Taisia Stadnichenko.*

► THE DIFFERENCES in value of the atomic weights of neighboring elements represent a gradual change in which we can follow their periodicity. This permits theoretical correction of the atomic weights of those elements which were determined with insufficient accuracy at first. I now want to clarify further some of the conclusions in regard to the properties, chemical as well as physical, of those elements which are lacking in the system and have not yet been discovered, but whose discovery is very probable. I think that heretofore there has been no possibility of foreseeing the absence of this or that element because we had no rigid system of elements and even more we had no reason to predict the properties of such elements. With the indications of the periodic and "atomological" relationships between the atomic weight and

the properties of all the elements it becomes possible not only to show the absence of some of them but also to determine with greater certainty and positiveness the properties of the at present unknown elements. We can now state their atomic weights, their density in the free state or in the form of oxides, their acidity or alkalinity, their degree of oxidation, their capacities for reduction and the formation of double salts, indicating the properties of the metallo-organic compounds and chlorides of the given elements, and we are even able to describe in considerable detail the properties of some of the compounds of these unknown elements. I have the courage to do this because, at some time in the future, when one of the bodies predicted by me is discovered, I shall have the chance finally to assure myself and to make other chemists believe in the correctness of those propositions which lie at the root of the system proposed by me. Personally I have been thoroughly convinced of the theory since the hypotheses for Indium, based on the periodic relationship that underlies all of this research, have been confirmed.

## Ekaboron

In the list of ordinary elements, the absence of a large number of analogues of boron and aluminum is most striking, that is, elements that belong to the third group. The lack of one element from this group, that ought to follow aluminum and ought to be found in the second series, following potassium and calcium, is quite evident. Since the atomic weight of the latter is close to 40, and since in this series we have an element of the fourth group, Titanium, with atomic weight of 50, the absent element must have an atomic weight of about 45. Due to the fact that this element belongs to the even series, it must show more basic properties than the lower elements of the third group, i.e., boron and aluminum. Its oxide  $R_2O_3$  must be more strongly basic. This can be proven by the fact that the oxide of titanium,  $TiO_2$ , has the properties of a very weak acid and also possesses many properties that are distinctly basic. However, the basic properties of this metal must be quite weak, because the basic properties of Titanium are so weak; in comparison with aluminum oxide, this oxide will have a more basic character and therefore it will not form with alkalis a stable compound which is not decomposed by water. But with acids it will form stable salts. At any rate, it will not be soluble in ammonia, but it is possible that its hydroxide will be slightly soluble in potassium hydroxide, although this is doubtful at present, owing to the fact that this element belongs to the second series and to the group of elements whose oxides contain a small proportion of oxygen.

I propose to call this element ekaboron, deriving the name from the fact that it follows boron as the first element of the even group, and a prefix eka- from sanskrit meaning "one."  $Eb = 45$ . Ekaboron in the free state would be a metal with atomic volume of about 15, because in this series of elements as in all even series the atomic volume diminishes rapidly in transition from the first group to the following one. Thus the volume of potassium is close to 50, of calcium to 25, of titanium and vanadium to 9, of chromium, molybdenum and iron to 7. The specific weight of this metal must be close to 3 because its atomic weight is 45. This metal will not be volatile, because all the metals of the even series in all groups (except I) are not volatile. Therefore it is not likely that it will be discovered by the ordinary method of spectral analysis. It will not decompose water at ordinary temperatures, but will decompose it at a slightly elevated temperature, similarly to other metals in this region, and a basic oxide will be formed as a result. It will dissolve, of course, in acids, and the chloride  $EbCl_3$  (maybe  $Eb_2Cl_6$ ) will be volatile, but salt-like, because it corresponds to the basic oxide. Water will affect it in the way it affects chlorine compounds of calcium and magnesium, i.e., ekabor chloride will form hygroscopic substances which will give HCl with water, but will have no chloranhydride character. Since the volume of  $CaCl_2$  is 49, and  $TiCl_4$  is 109, the volume of Ekabor chloride must be near 78, and consequently its specific weight will be close to 2.



The oxide of Ekaboron,  $\text{Eb}_2\text{O}_3$ , must be non-volatile, and possibly non-fusible, and insoluble in water, because even the oxide of calcium is only slightly soluble in water, but it will be soluble in acids. The specific volume of the oxide of Ekaboron must be close to 39, because in this series  $\text{K}_2\text{O}$  has a volume of 35,  $\text{CaO}$  of 18,  $\text{TiO}$  of 29 and  $\text{CrO}_3$  of 36. That is, with a content of one atom of oxygen the volumes at first rapidly decrease and then slightly increase, as can be seen from the following: volume of  $\text{K} = 35$ ,  $\text{Ca} = 18$ ,  $\text{Ti} = 10$ ,  $\text{Cr} = 12$ , therefore the volume for the oxide  $\text{Eb}$  with a content of one equivalent of oxygen ought to be about 13. Consequently the formula

### Ekaluminum

This cannot be said of the remaining elements of the third group in the even series, because their equivalents nearly approach those which should be possessed by the following unknown members of this group. In this group the element in the third series following zinc is lacking. Its atomic weight must be close to 68. We will call this element Ekaluminum,  $\text{El} = 68$ , because it follows directly after aluminum in the third group. In distinction from  $\text{Eb}$ , it must possess the ability to form metallo-organic compounds, and because of its position between aluminum and indium it must have properties close to those two elements. Consequently it will form alums. Its hydroxide will be soluble in a water solution of potassium hydroxide. Its salts will be more stable than the salts of aluminum, thus Ekaluminum chloride will be more stable than aluminum chlo-

$\text{Eb}_2\text{O}_3$  must correspond to a volume of about 39, and therefore the oxide of  $\text{Eb}$  in the dehydrated state will have a specific gravity of approximately 3.5. Being a rather active base, this oxide must show a slight tendency to the formation of alums, although it is possible that it will form alum-like compounds, that is, double salts with potassium sulphate. Ekaboron, of course, will not form metallo-organic compounds. From analogy with the elements of the even series, judging from the data at hand on the elements accompanying cerium, not one of them could fill the place of Ekaboron. Therefore this metal almost certainly does not belong to the number of satellites of cerium known at present.

ride. Its atomic volume, based on consideration of the same characters as were applied in determination of the properties of Ekaboron, must be close to 11.5, hence the specific weight in the metallic state will be near 6.0. The properties of this metal in all respects must represent the transition from the properties of aluminum to the properties of indium. It is very likely that the metal will possess greater volatility than aluminum, and therefore we may hope that it will be discovered by spectro-investigation in the way indium and thallium following it have been discovered, although it will be less volatile than either of them and therefore we must not expect such striking spectral phenomena as led to the discovery of the latter. Most probably this element also does not belong to the number of cerium's satellites, although its equivalent approaches the equivalent of

Yttrium. But it has not the form of oxide typical of Yttrium with the molecular formula RO, nor do the distinct basic properties of its oxide

## Ekasilicium

But it seems to me that the most interesting of the undoubtedly absent metals will be that which belongs to group IV of the analogues of carbon, namely, to the third series. It will be the metal directly following silicon, and therefore we will call it Ekasilicium. Ekasilicium must have an atomic weight of about 72, because it is followed in this series by arsenic. In character, Ekasilicium will have properties intermediate between silicon and tin, just as Ekaluminum must have properties intermediate between aluminum and indium. Es (rather easily reduced from  $\text{EsO}_2$  and  $\text{K}_2\text{EsF}_6$ ) must have a volume of about 13, as the volume of Si is 11 and the volume of Sn is 13. We will get the same results if we refer to the third series and go in the direction of Zn, the volume of which is 9, then to El, Es, then As, the volume of which is 14, and then go to Se = 18 and Br = 27. In this, as in the following odd series, the volume gradually increases from Cu to Br. Consequently free Es must have a specific weight of about 5.5. Its remaining properties will resemble the properties of Si and As to such an extent as the properties of As itself resemble the properties of P and Se, that is, it will at any rate be a fusible metal capable at high temperatures of volatilizing and oxidizing. It will decompose water vapor with difficulty. It will have almost no action on acids, that is, it will not liberate hydrogen and it will form

permit us to consider Yttrium as belonging to this place in the system of elements; instead the next place, in the third series, position III-4, belongs to Yttrium. . . .

very unstable salts. Alkalies will react on it similarly to their action on zinc and arsenic.  $\text{EsO}_2$  must have a specific volume close to 22, because that is the volume of the oxide of silicon and of the oxide of tin, and therefore a similar volume will be obtained by reasoning from the properties of other oxides of elements belonging to the third series. Thus the specific weight of the oxide of this metal must be close to 4.7. In regard to the basic properties of this oxide, they must be very slight, for in silica they are almost absent and in the tin oxides they are also slightly developed, and therefore the properties of this oxide must be expected to be closer to those of titanic acid. Undoubtedly it will form a gelatinous hydrate which can be dissolved in alkalies and acids, from which it can be separated easily in various ways, as is noted with titanic acid. However, in comparison with the latter, the oxide of Es will possess more clearly defined acidic properties. Thus if Es accompanies titanium in its compounds we must think that, all other conditions being equal, Es would precipitate from an acid medium before titanic acid, while in an alkaline medium it would come down after titanic acid. By these few indications pointing to it, one can be guided in research for these elements in compounds of titanium and zirconium in which many investigators have already tried to find new elements. . . .

Es, like all metals of this group, will form with HF an acid of the composition  $H_2EsF_6$ , which can form salts isomorphous with the salts of hydrofluosilicic acid, but it is most likely that Ekasilicium fluoride itself will not be a gaseous compound, as zirconium fluoride and tin fluoride are not gaseous. Ekasilicium chloride will not be decomposable by water, as are silicon chloride and tin chloride, and in this relation it will present properties intermediate between the latter two. It is possible that it will be a liquid, and will have a partial volume of about 113, because the volume of silicon chloride is 112 (at  $0^\circ$  Pierre) and the volume of tin chloride 115 (at  $0^\circ$  Pierre), hence the specific weight of Ekasilicium chloride will be about 1.9. The ability to deoxidize into lower forms of oxides will be slightly developed in Es and in this relation as in the others it will come nearer to titanium. The boiling temperature of Ekasilicium chloride must be close to  $90^\circ$ . It will undoubtedly form metallo-organic compounds, as they are formed by Si, Sn, Zn and As. It will be "atomologic" with them. In this it will differ from Ti and Zr, in which this property is not developed.  $EsEt_4$  will boil at  $160^\circ$ , and will have a specific gravity of 0.96. We might expect that it will have a hydrogen compound and its properties will be very definite, namely  $EsH_4$  will readily decompose into water and metal, because even arsenic hydride possesses this property similarly to lithium hydride. At any rate, the existence of hydrogen compounds with this metal is more probable than it is for tin, and even for tin we might expect tin hydride,  $SnH_4$ , as a gaseous substance but very unstable. Based

on this indication it seems to me more probable to find Es in the compounds of titanium and zirconium, although the purification of the minerals containing these elements, owing to the weak oxides of Ti and Zr, presents considerable experimental difficulty. It seems to me most advisable to search for Es in perovskite (perofskite), i.e., a calcium titanite salt sometimes found in nature. I think this because oxide of titanium possesses very weak acidic properties, nevertheless with lime it forms well crystallized cubic perovskite whose occurrence is probably to some extent due to the fact that part of the titanate acid is replaced by the oxide of Ekasilicium. It may be that the majority of ordinary titanium compounds, especially those that are obtained from  $TiFeO_3$ , eshenite, and similar ones, contain besides titanium an admixture of some similar element with a higher equivalent, because on comparing the equivalent of titanium with the equivalent of the neighboring elements we can see that it is somewhat high. The transition from  $Ca = 40$  to  $Ti = 50$  is too rapid and from  $Ti = 50$  to  $V = 51$  is too slow, and if Ti in reality possessed an atomic weight of about 48 the relation of its atomic weight to the weights of the other neighboring elements would be more regular. It may be, again, that the determination of its atomic weight is not correct because titanic compounds can not be prepared in a very pure state because the properties of titanic acid are not distinct. There are only two forms in which titanium can be separated well from admixture, namely, volatile titanium chloride—but of course no substance has yet been obtained in a pure state in the form of a volatile

compound—and another form,  $\text{TiK}_2\text{Fe}$ , but such compounds are also formed by Ekasilicium. At any rate, more accurate experiments on the determination of the atomic weight of titanium are not without great interest.

The indications given above for the properties of expected elements could not appear to anybody as devoid of a firm foundation, and it would be a considerable addition to the theoretical side of the problem if one of the expected elements should be definitely discovered and its properties should prove such as might be expected through a comparison based on the natural system in which we have placed the elements according to their atomic weights. Besides these certainly probable ones, there is a possibility of other undiscovered elements, even whole groups of others, whose existence is to some extent doubtful because we know nothing of the nature of the forces which produce the so-called elementary forms of matter. We have full right to judge of the elements that are found in the center of the system within the limits in which many of the elements are well known, but we cannot say the same of the elements that must be placed at the extreme parts of the system. It may be that certain equilibria, i.e., the existence of certain "atomologues," are simply impossible, just as certain members of homologous series, under all the conditions necessary for their formation, are not obtained but are transformed into other, more stable polymeric or different forms, as in the case of methylene, for instance. It is possible also that there exist elements with lower atomic weight, between 1 and 7, occurring

between hydrogen and lithium, and elements in Group VIII with atomic weights of about 20, i.e., located between fluorine and sodium, like the iron group found between manganese and copper. I would like to draw attention to a striking fact, that in the system of elements at present 17 elements are absent (i.e., a complete two-series period) having atomic weights from 138 to 182. This phenomenon could hardly be accidental, since among the elements with lower atomic weights and also among the elements with higher atomic weights we already know many members. Into this space it is possible to put some of the cerium metals, because if we give to their oxides the composition of  $\text{R}_2\text{O}_3$  or  $\text{RO}_2$  we obtain for them atomic weights from 140 to 180, if the accepted equivalents as determined at present are sufficiently accurate. Among other elements with small atomic weight we might expect one more analogous with manganese than with titanium, belonging to the platinum group having a smaller atomic weight than ruthenium, namely about 100, referred to Group VII and capable of forming a salt  $\text{KRO}_4$ , similar to potassium permanganate. It may be that the elements analogous with sodium in Group I and possessing atomic weights close to copper and silver exist, although the lighter metals are able to form, like sodium, the compounds  $\text{RHO}$ ,  $\text{RCl}$ , etc. and therefore it may be that they make the transition from elements of the eighth group to elements of the second. Among the heavy metals, that is, those with large atomic weights, we might expect an element analogous with tellurium and having an atomic weight greater than bismuth. It ought

to have distinctly metallic properties, the ability to form an acid similar to sulphuric acid, but an even stronger oxidizing agent than telluric acid. The oxide of this element  $\text{RO}_2$  found in VI-9 ought to be a fairly strong base, like the oxide of bismuth—we cannot expect acid properties for the oxide  $\text{RO}_2$  in this place. This element ought to form metallo-organic compounds. Hydride compounds very likely will not exist because with increased atomic weight and increasing basic metallic character of the element, the tendency to combine with hydrogen, as has been noted in the transition from chlorine to bromine and iodine, decreases. Then in the 10th series we might expect basic elements belonging to Groups I, II and III. They must have atomic weights of about 210-230. The first of them must have the oxide  $\text{R}_2\text{O}$ , the second  $\text{RO}$ , and the third  $\text{R}_2\text{O}_3$ . The first will be similar to cesium, the second to barium, and all their oxides will have the character of strong bases, because in this series (10) even thorium in its oxide  $\text{ThO}_2$  has distinctly basic properties, and even uranium of the same series in its oxide  $\text{UO}_3$  still has a clearly basic character. Between thorium and uranium in this series we must expect another element with basic properties, although slightly developed, with an atomic weight of 235. This element must form an oxide of higher degree of oxidation with the composition  $\text{R}_2\text{O}_5$ , like columbium and tantalum, with which it ought to be analogous. It is possible that in the minerals containing these elements small amounts of weak acids formed by this metal are found.

The tenth series ends the elements

now known, and as in the series of typical elements we found many acid-forming elements while that phenomenon was not repeated in the following series, so in the 10th series we found many base-forming elements and this also is not repeated in the other series, from this we can conclude that here we are close to the end of the possible forms of elementary compounds. Confirmation of this supposition can be seen in the fact that the atomic weights of the elements in the first series differ between the groups by about 16, but in the following series this difference reaches 25 and even more, while the difference between neighboring elements in the last series is again decreasing.

The use of the principle of periodicity in the search for undiscovered elements and in the determination of their properties, in my opinion, presents the most striking form of the discussion as to the practical application in scientific research of the chemical data derived from the natural system of the elements as based on the sum total of knowledge at hand concerning the already known elements. Without undue exaggeration of the apparent advantages of such a system, we must finally recognize its correctness, at any rate, after the properties of unknown elements, predicted on the basis of it, will have been confirmed by actual discovery. Then all must admit that heretofore chemistry did not have any means of foreseeing the existence of new simple bodies and if they were discovered they were found only by means of actual observation. I think that the use of the proposed system of elements for comparison of the elements them-

selves, as well as the compounds which they form, presents, even at present, advantages which have not been given by any conception used in chemistry heretofore. But for the final proof of the correctness of the conclusions based on the use of the system, the establishment of certain additional facts is necessary, especially more accurate determination of the atomic weight of certain elements and determination of the physical properties of some of their compounds. When it becomes possible to subject

the periodic function of the properties of atomic weight and "atomologic" relationship of the elements to exact laws, then we will approach a closer understanding of the real essence of the difference between the elements themselves. Then of course chemistry will be able to leave the field of hypothetical conceptions ruling it at present and then it will be possible to give it dynamic direction already so fruitfully employed in the study of many physical phenomena. Nov. 29, 1870.

### *"Useless" Research Speeds Vitamin Synthesis*

► THERE IS NO such thing in chemistry as useless fundamental research.

Dr. Lee Irvin Smith of the University of Minnesota, told the Akron Section of the American Chemical Society recently that years of apparently useless investigation, conducted solely for its academic interest, enabled the Minnesota scientists to speed the synthesis of Vitamin E, the anti-sterility vitamin, once they tackled the problem.

Any research which is fundamental is worth doing, however 'useless' from a practical point of view it may seem at the time, for it can never be predicted when some of these 'useless' researches will assume great importance and will form the starting points in an attack upon some urgent commercial problem.

So the early 'useless' work thus does not have to be done when the urgent related problem appears, and much time is saved because the background has already been constructed.

Two seemingly unrelated lines of research contributed to the rapid pro-

gress made on Vitamin E. The first, begun in 1922, concerned the reactions between two types of compounds, alkylated quinones and metallic enolates, and the second dealt with benzene products called polyalkylbenzenes and polymethylbenzenes. As a result of these studies, a great many new compounds were prepared.

Later, when the probable structure of the Vitamin E factor alphatocopherol was suggested, the Minnesota chemists found that not only was it a simple matter to carry out model researches in support of this theoretical structure, but that in many instances the model researches did not have to be carried out. They had been performed already and the resultant compounds were on the laboratory shelves.

As a result, the Minnesota group knew exactly how to synthesize alphatocopherol after working but a month or two on this specific problem. Thus the work of over 15 years, done purely for its academic interest, made possible the synthesis of alphatocopherol in a matter of less than six months.

## Methane Gases Rich in Hydrogen Atoms Found in Satellite's Atmosphere

### Gases Formed After Titan Cooled

► THE ATMOSPHERE which surrounds Titan, Saturn's largest moon, was formed after Titan had cooled off. Should Titan, the only satellite in the solar system known to have an observable atmosphere, become more than twice as hot as it is today, its atmosphere would escape entirely, reports Prof. Gerard P. Kuiper of the McDonald and Yerkes Observatories of the Universities of Texas and Chicago.

"If Titan has gone through a period with a high surface temperature, as is commonly assumed to be true for all bodies in the solar system," Prof. Kuiper states in the *Astrophysical Journal*, "then it follows that Titan's atmosphere was formed subsequent to that period."

It is of special interest that, like Saturn itself, Titan's atmosphere con-

tains methane gases that are rich in hydrogen atoms. Such gases had previously been associated with bodies having a large surface gravity.

It is highly probable, he states, that Titan was formed within Saturn's system instead of being captured from some other planet. The color of Titan is orange, in marked contrast with Saturn and its other satellites, which are yellow. This difference, however, may be due to the atmosphere acting on the surface of the satellite.

The discovery of atmospheres for other satellites would probably throw light on their creation. After studying with a spectroscope the ten largest satellites in the solar system, Prof. Kuiper suspects that of these Triton, Neptune's only satellite, may also have an atmosphere. Further study will be needed to settle the question.

### Alumina Has Lower Melting Point

► ALUMINA, the common oxide of aluminum which is used as an essential ingredient of super-duty spark plug insulators, high-temperature refractories, and insulators in the field of electronics, has a lower melting point than previously supposed, it is determined by the National Bureau of Standards.

As a result of recent measurements made by R. F. Geller and P. J. Yavorsky of the Bureau staff, the melting point of alumina has been determined

as lying within the range 3630 to 3690 degrees Fahrenheit. This is lower than the value usually quoted, 3720 degrees.

A reasonably accurate knowledge of the melting point of this material is important because of its wide industrial uses. Three samples containing over 99.9 per cent of alumina were used in the tests. They were heated in an oxidizing atmosphere in an electric furnace, and the temperatures determined by means of an optical pyrometer.



**Making Big Ones Out of Little  
Molecules Industrially Useful**

## Polymerization Explained

by DR. PAUL O. POWERS

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➤ SYNTHETIC resins and synthetic rubbers may be described as polymers. A *polymer* is a large molecule formed by the chemical combination of several molecules. The term large is somewhat wide in scope and may include materials 500 to 500,000 in molecular weight. The small molecules which unite to form the large molecule may all be the same or of two, three, or four different molecular species. The process by which they are formed is polymerization. The starting material is the *monomer*, and the polymers are designated by the Greek prefix relating to the number of molecules which are united in the polymer. Thus, two molecules form a dimer; three a trimer; four a tetramer. The simplest repeating unit in a polymer is a *segment*, which is not necessarily identical with the monomer in chemical composition.

The skeleton of polymers often consists of long chains of carbon atoms, although oxygen, nitrogen, or sulfur may also be present in these chains. These chains may vary in length from ten to ten thousand carbon or other atoms. Side groups are not necessarily present, but in most polymers we find alkyl, aryl, halogen, nitrile, alcohol, ester, ketone, or other groups. The properties of the polymer are greatly modified by the nature of these side groups. Polymers of this type are

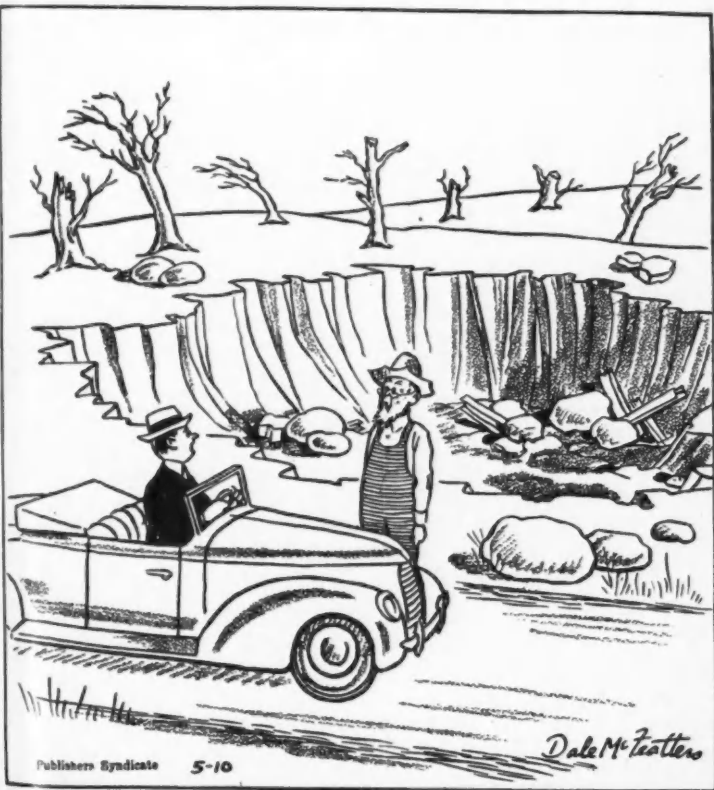
linear polymers. In certain polymers it is believed that the long chains are attached to several shorter chains of the same type, forming branched polymers. Also, it is possible to introduce bonds between the long chains. These bonds may be comparatively few, only one or two to a chain, and the polymers thus formed are cross-linked polymers. Linear polymers are usually fusible and soluble whereas cross-linked polymers are insoluble and infusible.

Polymers are formed by two methods, condensation polymerization and vinyl polymerization. In condensation polymerization, a by-product, often water, ammonia, hydrogen chloride, or sodium chloride, is formed in addition to the polymer. The polymer, therefore, has a different ultimate analysis from the monomer. In vinyl polymerization, the monomeric molecules react to form the polymer without forming any other products, and the ultimate analysis of the polymer is the same as that of the monomer. For this reason this type of polymerization has also been termed addition polymerization. Vinyl polymerization is so called because many of the materials which polymerize in that manner may be considered as derivatives of vinyl alcohol,  $\text{H}_2\text{C}=\text{CHOH}$ . When two or more types of vinyl compounds are combined in the poly-

mer, the product is a copolymer. The term interpolymer is also used.

Certain side groups in polymer chains have a much greater tendency to establish forces between chains than others. With a long chain and many points of contact, the effect of these forces may be considerable. H. Mark, *Ind. Eng. Chem.* 34, 1343, (1942), has recently suggested that the nature of a

polymer is largely dependent on the type of side groups. If  $\text{—OH}$  or  $\text{—NH}$  groups are present, as in cellulose or proteins, there is large interaction by hydrogen bonding, and the polymer is a fiber. If there is little interaction between the long chains, as in hydrocarbons, the polymer is a rubber. In resins, the forces are intermediate between fibers and rubbers.



Publishers Syndicate

5-10

Dale McTeather

"Wasn't there a powder plant around here?"

## Rare Element Plays Major Role In Machine Industry

# Tungsten, Speed Metal

by E. W. NELSON

➤ TUNGSTEN is one of the most fantastic of all metals—almost a metal of another world. It is one and two-thirds as heavy as lead (the name “tungsten” derives from two Swedish words meaning “heavy stone”); it has the highest melting point (over 6098 F.) of any metal; and in wire form it has a tensile strength twice that of alloy steel.

The uses of tungsten are as fantastic as its properties. The world has never used more than a few thousand tons of it a year, yet day and night we benefit from it in the form of electric lights; it has made possible our modern era of mass production; it enabled the German munition industries to get the jump on the Allies in 1941 and prolong that war; it enabled Hitler to build his deadly war machine in six years before World War II; and finally it helped the United Nations out-produce Nazi-dominated war industries.

Although tungsten ores have been known for centuries, scientists before 1781 had but a vague idea as to their composition. Most miners thought they were some peculiar kind of tin ore. In 1781, however, Carl Scheele showed that the ore—which was named “scheelite” in 1821 by Leonhard in Scheele's honor—is a compound of lime and a peculiar acid. This event foreshadowed the discovery of a new metallic element. Whether or not Scheele isolated tung-

sten before 1783 is not known, but in that year two Spanish chemists—J. J. and F. de Elhuyar—published a paper proving that they had isolated tungsten and also that, in the ore “wolframite,” tungsten is associated with manganese and iron instead of with calcium as it is in scheelite. The next important event occurred in 1847 when the English investigator, Oxland, took out a patent for the manufacture of sodium tungstate and tungstic acid, two compounds which form the starting point of all tungsten metallurgy.

In 1868, the English metallurgist Mushet produced a steel containing 5%-8% tungsten. This steel hardened when cooled in air and did not need a water quench to develop its properties. Moreover, it formed the best cutting tool metal the world had ever seen up to then and reigned supreme in the field of cutting tools until 1900. It was in that year—at the Paris Exposition—that the Bethlehem Steel Company exhibited the forerunner of modern high speed cutting steel. This was an alloy steel containing about 18% tungsten; 4% chromium; and 1% vanadium. It was the first time that tungsten steel had been brought to the attention of the general public and it created a sensation inasmuch as it out-cut and outlasted Mushet's famous “self-hardening” steel.

It was not until 1909, however—when Dr. W. D. Coolidge of General Electric took out his patent for ob-

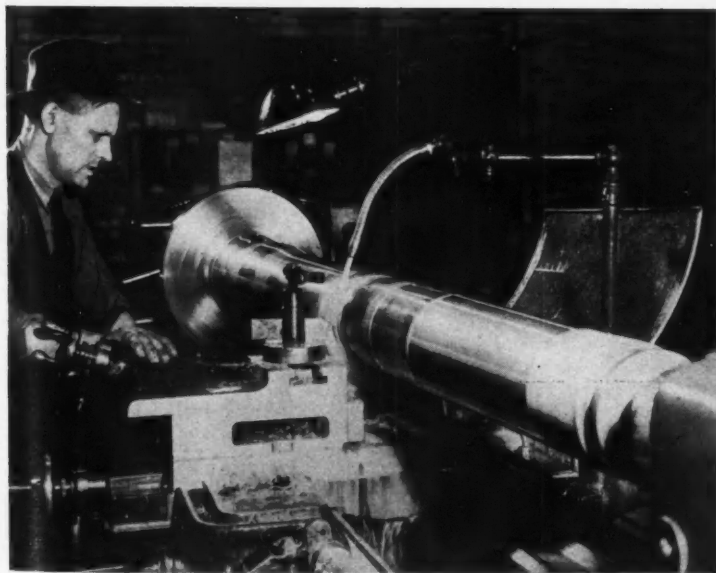
aining pure tungsten powder by reducing tungsten oxide in a furnace in the presence of hydrogen—that the real development in the use of tungsten filament wire for electric light globes really began.

### Rare Element

Compared to other useful elements, tungsten is a “rare,” though not a “precious” metal. It rates as the 38th element in order of its occurrence in the earth’s crust. Unlike the ores of certain other strategic metals tungsten ore is quite widespread in na-

ture. Every continent has numerous ore deposits, although most of them are of rather low grade.

Prior to the beginning of World War II, the United States annually consumed some 5000 short tons of tungsten and produced about half that amount. Present consumption can only be estimated but will certainly exceed 10,000 tons per year and may be double that. In times past, 80% of our tungsten imports were from China which is the world’s leading producer of this metal (with India



► By speeding up machining processes, tungsten carbide—in the form of tips for metal cutting tools—helped the United States armament production. In the operation shown here, use of carbide tools permits machining four 105 mm. howitzer barrels in the time formerly required to produce one barrel with ordinary tools. A total of 600 pounds of metal is removed from each of these cast steel barrels during the turning and boring operations.

and the United States in the past a poor second and third). With the falling off of shipments from China, our country has been developing the resources of Argentina and Bolivia as well as paying deposits within our own borders. The most recent figures on American production show a material increase in the past few years.

The melting point of pure metallic tungsten is so high that in actual production and use it is never melted. Recovery from the ore is generally made in one of two ways. In the first method, a "master alloy" called "ferrotungsten," is prepared by heating an ore of rather high iron content together with charcoal in an electric furnace. The product contains about 80% tungsten and is added to the molten steel in varying amounts as needed to produce the various grades of tungsten steel now available.

### **Metallic Tungsten**

Production of metallic tungsten involves fusing the ore with sodium carbonate, which gives sodium tungstate with impurities of iron and manganese oxides. On being dissolved in water, the tungstate remains in solution whereas the oxides are filtered out. The sodium tungstate is treated with hydrochloric acid which precipitates impure yellow tungstic acid. The acid is purified and brought to heat, producing a tungsten oxide. Heated in an atmosphere of hydrogen, this oxide is reduced to metallic tungsten in the form of heavy grey powder. When this powder is pressed and sintered into hard bar form, tungsten has a steely luster.

Tungsten is added to steel in amounts ranging from less than 1.0% to around 20.00%. It makes steel

tougher, stronger, and gives it a somewhat higher melting point. The lower percentage tungsten steels are used for special tools; wire drawing dies; permanent magnets; etc. The military uses of tungsten steels include armor plate; armor piercing shells; gun breeches; and erosion liners for heavy ordnance and guns that get red hot in action.

Various grades of high speed steels—containing between 6.00% and 20.00% of tungsten with or without molybdenum and some chromium and vanadium—have the remarkable property of "red hardness," or of remaining hard at high temperatures. They are not appreciably softened even at red heat. Metal cutting tools made from the best plain carbon steel must be kept cool and the work run slowly to keep an edge on the tool. When tungsten steels were introduced, larger cuts could be taken at faster speeds. It has been estimated that with high speed steel cutting tools, one man with one machine was in many cases able to do the work of five men with five machines tooled with plain carbon steel tools. Thus, tungsten was responsible for the great age of mass production and high speed machining which got its real start during World War I.

In the electrical industry, tungsten is used principally as filament wire—drawn out from solid metal ingots—for both electric lights and radio tubes. Vitaly important as this application is, these purposes take less than 100 tons of tungsten per year. In fact, the lights in an average house contain about one cent's worth of tungsten. More than two hundred different kinds of contact points for

airplane magnetos, automobile distributors, etc., are formed from sheet or bar tungsten.

### Cemented Carbides

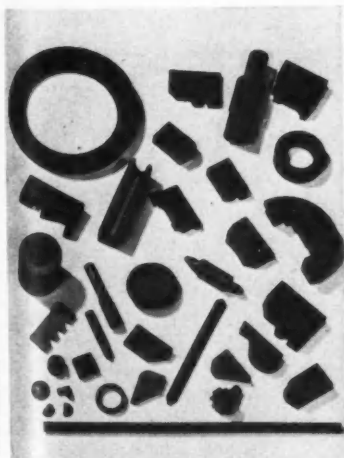
Perhaps tungsten's most vital contribution to modern civilization is its use as the major ingredient of tungsten carbide, the hardest metal made by man. Hard cemented carbide was first used commercially—in a limited way—in Germany during World War I as a wire drawing die material in place of diamonds which were unobtainable in that country at that time. In 1927, there was exhibited by Krupp a patented mixture of cemented tungsten carbide with up to 10% of cobalt under the name of "Widia."



➤ *THIS DIE for the deep drawing of sheet metal is composed of a large steel case in which is supported the cemented carbide die "nib." The nib alone weighs over 100 pounds. A die of this type stands up under the severe wear of drawing steel, including sheet; wire, bar stock and forgings, many times longer than dies made from tool steel.*

Solid carbide cutting tools were imported into the United States from Germany but proved impractical. After several years of research, General Electric Company set up Carboloy Company to develop, manufacture, and distribute cemented carbides. Since the time when Carboloy Company was established, the use of carbides has expanded to such an extent that today, carbides have become a vital factor in industry. It is estimated that in the field of metal working alone, cemented carbide tools are now being used for a substantial part of all metal removal and are largely replacing high speed steel.

In the field of metal cutting alone, carbide tools have so improved and speeded up machining practices that their widespread use since the start of World War II has been a large factor



➤ *SOLID CARBIDE articles are manufactured on a mass production basis. The largest parts shown are between three and four inches in diameter. Some are complete parts. Others are inserts.*

in enabling the United States to overcome Germany's tremendous lead in the armament race and to finally out-produce all the rest of the United Nations. In addition, the use of tungsten carbide in the form of cutting tool tips has greatly conserved our supply of this hard-to-get metal. It has been estimated that if it had been necessary—and possible—to use ordinary 20.00% tungsten steel for machining all of the metal which has been cut since the beginning of the war, it would have required more tungsten than we had available just to make the high speed steel for the cutting tools.

### Method of Manufacture

Cemented tungsten carbide as manufactured by Carboloy Company is a cemented metal in the strict sense of the word. Its composition is characterized by structure in which finely divided particles of tungsten carbide are held in a binder or matrix of a relatively softer and less refractory material. The structure of the metal somewhat resembles that of a brick wall. The carbide particles represent the bricks; the cobalt (or other binding material) serves as the cement which holds the bricks in place.

At normal temperatures, the hardness of tungsten carbide particles may equal or approach that of the best abrasive grains. They are not quite as hard as diamonds. Most important, perhaps, of the metal's characteristics, is its "red hardness." Carboloy cemented carbide is as hard at 1550° F. as high carbon steel is at 650° F. or high speed steel at 825° F. This red hardness is extremely important when carbides are used for cutting tools. Furthermore, even at normal tempera-

tures the tensile strength of cemented carbides approximates one-half to two-thirds that of tool steel. As a result of these characteristics Carboloy cemented carbides also inherently possess extremely high resistance to wear caused by rubbing or abrasion.

While the basic ingredient of Carboloy cemented carbide is tungsten carbide, supplementary ingredients—titanium and/or tantalum carbides—are sometimes added when it is desired to provide certain basic properties such as are needed for instance in tools used for steel cutting operations. Tungsten carbide is prepared by firing a mixture of tungsten powder and lampblack at a temperature of about 2700° F. The carbide is mixed with the cobalt binder and the resultant powder formed into the required shapes by either (1) cold pressing followed by sintering to develop the full hardness and strength of the metal; (2) hot pressing, which combines pressing and sintering in one operation; and (3) extrusion, by means of which round rods are produced on a commercial basis.

In general, the uses of Carboloy cemented carbides fall into three major classifications—(1) as a cutting tool metal; (2) as a die metal; and (3) as a wear-resistant metal.

### Machining with Carbides

At present, the greatest use of carbides is in machining where it offers greater cutting efficiency than can be obtained with any other tool material. Tools for cutting are generally made up with the cemented carbide portion in the form of a cutting tip brazed to the remainder of the tool, which is usually a "soft" steel shank or cutter body. This is practical because when



cemented carbide is used for cutting, wear is so slow that actually only a small tip is necessary to produce excellent results.

Carbide tools are being used commercially to cut the entire range of steels, cast irons, and malleable irons up to 550 Brinell hardness. In addition, practically all of the commonly used non-ferrous metals and such non-metallic and abrasive materials as hard rubber, "Bakelite," celluloid, "Textilite," "Lucite" and other plastics, asbestos, porcelain, Masonite, carbon, etc., are all being cut today with carbide tipped tools.

Chief among the advantages of carbide tools are that they remove more cubic inches of metal per minute than other tools, hold closer tolerances at high machining speeds; give longer tool life; and produce a better finish on the work piece. The large volume of carbides now being produced has lowered the one-time high cost of this metal to a point where the price of carbide tools compares favorably with the cost of other tools for similar purposes.

### **Tungsten Carbide Dies**

The original use of carbides—as a die material for drawing round wire—continues to be such an important application that carbide dies are no longer regarded as a spectacular innovation but are generally considered standard throughout the wire industry. In this country, most of the wire footage is produced with carbide dies. They permit working to closer tolerances on the finished product and give a greater uniformity of product together with a better finish than do ordinary dies. In addition,

carbide dies last longer, thus decreasing the amount of time wasted in replacing and servicing worn dies.

In the field of sheet metal drawing, the chief value of carbide dies is the metal's extremely high resistance to wear. Added impetus to this phase of Carboloy cemented carbide's usefulness was given by the War Program in connection with the manufacture of cartridge cases—first from brass and then from steel. For the brass cases, experience showed that one Carboloy cemented carbide die did the work of twenty average tool steel dies. When the copper shortage made it necessary to substitute steel for brass as a cartridge case material, this conversion would have been practically impossible without carbide dies and their ability to withstand the terrific abrasive action attendant to the deep drawing of the steel cases.

### **The Future**

As a wear resistant metal, tungsten carbides are now being used—both in the form of shaped inserts and for complete parts—where undue wear caused by abrasion is a problem. Typical applications for this general purpose include ring and plug gages; indicator points; fish rod guide rings; liners for molds for bricks, drugs, and powdered metals; lathe and grinder centers; etc.

Based on the performance of cemented carbides during the past few years, it does not seem too far-fetched to prophesy that the industrial world will utilize more and more the peculiar properties of tungsten, a metal made available to engineers only by the unflagging research work of chemists and metallurgists.

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